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I. THE SOCIETY

RECENT DEATH

KEENAN, W. N. died at Ottawa, Ontario on 11 March 1980 at age 88. He was a former director of Plant Protection Division, Agriculture Canada, an honorary member of the Entomological Society of Canada and a former member of the Entomological Society of Ontario.

PRESIDENT'S PRIZE — 1979

Jon Houseman, Department of Biology, Queen's University, won this year's "President's Prize" for the best student paper presented at the annual meeting in November at the Parkway Inn, St. Catharines, Ontario. His paper entitled "Proteinase Activity in the Posterior Midgut of *Rhodnius prolixus* Stål. (Hemiptera: Reduviidae)", was judged the best of eight in the competition.

Mr. Houseman was born in Montreal, Quebec and moved to Ontario in 1970. He received a B.Sc. Honours in Biology in 1976 from Queen's University and a M.Sc. in Entomology from the University of Alberta in 1978. He returned to Queen's in 1979 for graduate study under the joint supervision of Dr. A. E. R. Downe and Dr. G. R. Wyatt. The objectives of his research were: 1) to identify the digestive proteinases in *Rhodnius prolixus*, 2) to determine whether the proteinases found in this species are similar to those found in other blood feeding Hemipteran insects and, 3) to determine the factors controlling the production of digestive proteinases in *R. prolixus*.

This is the second award for Mr. Houseman this year. He was awarded a 1979 Ontario Graduate Scholarship and was recently awarded a National Sciences and Engineering Research Council Post Graduate Scholarship for 1980.

TED HEMING RETIRES AS EDITOR

After retirement from the University of Guelph in 1969, Ted Heming served as editor of the Proceedings from 1972-1977 and assistant editor in 1978 and 1979. He recently resigned his position and is in the process of moving to Burlington, Ontario. The executive and members of the Entomological Society of Ontario thank him for his most worthy service and wish him a successful second retirement.

DAVE PENGELLY RETIRES AS TREASURER



After 16 years of dedicated service, Professor Dave Pengelly retired from his position as treasurer of the Entomological Society of Ontario. Dave became a director of the Society in 1963-64 and then succeeded C. C. Steward as Secretary-Treasurer in 1964. This position was divided in 1976 and Dave continued as treasurer until 1979. He has spent many hours over the years at the sometimes thankless job of serving the society. He is one of the few remaining historians of the Society and has kept files and letters of some of our early members.

Dave obtained his Ph.D. from Cornell in 1955 and joined the Department of Entomology at the University of Guelph the same year. Research with graduate students has included work on dermestids, simuliids and dytiscids. However, his main interest is Hymenoptera, particularly the ecology and taxonomy of the Apoidea. Whatever the need, Dave always has time for the Society, students and colleagues. His genuine enthusiasm and encouragement in all areas of entomology has inspired many of his students to continue in research. In 1978, he won the exclusive "Alumni Distinguished Teaching Award" presented by the Ontario Agricultural College. The Society thanks Dave for his outstanding contribution of time and effort.

II. SUBMITTED PAPERS

EVIDENCE OF OVICIDAL ACTIVITY BY FUMIGANT ACTION USING CHLORPYRIFOS FOR CONTROL OF *HAEMATOPINUS SUIS* (ANOPLURA: HAEMATOPINIDAE)

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Abstract

Proc. ent. Soc. Ont. 110: 3-7 (1979)

In studies evaluating chlorpyrifos, Dursbane® 44, as a spot-on treatment for control of hog lice, *Haematopinus suis* (L.), 100% reductions were observed at dosages of ca. 10, 20 and 30 mg/kg. Similar reductions were observed on untreated animals, housed in the same barn, without physical contact with the treated animals. Eggs of lice on treated animals failed to hatch. Evidence is presented that suggests that the louse mortality resulted from a fumigant action.

Introduction

For control of lice with most presently registered insecticides, heavily infested animals should be retreated after 10-14 days. These materials, although effective against the adults and nymphs, do not kill eggs of lice attached to the hairs. After initial treatment, these eggs hatch and with little residual activity of the insecticide, there is a gradual increase in louse numbers. The concept of retreatment after 10-14 days is to ensure that all surviving eggs have hatched and that no new eggs have been laid thus eliminating the louse population. An insecticide that destroys all life stages including the eggs would eliminate louse infestations and thus avoid the necessity of a second treatment. Studies with chlorpyrifos for control of lice on cattle have shown this material to be highly effective with excellent ovicidal activity (Buchanan and Coles 1971; Loomis *et al.* 1976). Tests were therefore conducted to determine the effectiveness of this product for control of the sucking louse, *Haematopinus suis* (L.) on swine.

Materials and Methods

Thirty-five pregnant brood sows were divided into four test groups of eight to ten animals. Each sow was in an individual stanchion pen and test groups were separated such that no physical contact between groups was possible. All animals were housed in a low ceiling (ca. 2 m), poorly ventilated barn which had a single exhaust fan that ran continuously. The barn was completely enclosed with concrete floors, wood ceiling and sheet metal walls. At the time of this study no other insect control programs were ongoing nor had any spray programs occurred for at least two months. In addition to test animals, ca. 60 gilts and six boars were housed in the same barn and ca. 20 sows in a nearby non-connected farrowing barn.

One group of animals acted as controls and the others were treated at the rate of 10, 20 or 30 mg/kg. As no scales were available, sows were estimated to the nearest 20 kg by the producer. Sows ranged in weight from ca. 140-200 kgm. The non-treated animals were located furthest from the single exhaust fan to

minimize possible vapour effects. A louse index per animal was determined by the number of lice observed on the face, sides of neck and backline to the rear of the front shoulders. A pretreatment count was made on Oct. 5/78 and animals then treated using a single spot-on treatment of chlorpyrifos, Dursban®44. The ready-to-use formulation was applied from a plastic squeeze applicator to the centre of the backline at the rate of 1, 2, or 3 ml per 45 kg dependent on treatment group.

Many of the animals in the treatment barn were observed with large concentrations of louse eggs, particularly on the sides of the neck. Since no reinfestation had occurred by 28 days posttreatment, hair samples were removed from animals of each test group. Samples were also taken from sows in the nearby farrowing barn where adults and nymphs were still active. Samples were removed using electric clippers, coded by test group and examined in the laboratory within four hours. Eggs were classified as unhatched based on the presence of an operculum. Each unhatched egg was then squeezed with forceps until the chorion was broken. If embryonic fluid was present the egg was considered viable; if no fluid was present the egg was classified as desiccated and non-viable.

Results and Discussion

Immediately after treatment a strong insecticidal odor permeated the barn and was evident at the time of the first posttreatment count, 18 hrs later. The producer indicated that this odor persisted for approximately four days, but no adverse effects were noted to animals in the three treatment groups. These observations agreed with Loomis *et al.* (1976) who found no adverse effects to calves except three animals treated at dosages at least three times higher than those of this study. At dosages of 100-200 mg/kg cattle showed signs of organophosphate toxicity within five minutes but were fully recovered within 90 minutes (Loomis *et al.* 1976).

The effect of chlorpyrifos on populations of adults and nymphs is presented in Table I. Eighteen hours posttreatment no live lice could be found on any of the treated animals; whereas, louse indices on control animals remained similar. Post-treatment counts 6, 21, 28 and 42 days later also failed to reveal any lice on treated animals. Six days posttreatment no lice could be found on the non-treated controls. The producer insisted that these animals had been neither treated nor moved. Visual inspection of ca. 20 gilts and six boars which were not treated but housed within the same barn also revealed that these were free of lice despite having moderate infestations prior to treatment. Sows in the nearby non-connected farrowing barn were then examined and found still to have moderate infestations of lice.

TABLE I. Effect of chlorpyrifos (Dursban® 44) on populations of *Haematopinus suis*, Fergus, Ontario, 1978.

No. of Animals	Dosage	Mean Louse Index/Animal Posttreatment at Hours (h) and Days (d) indicated					
		Pretreatment	18 h	6 d	21 d	28 d	42 d
8	30 mg/kg	42.6	0	0	0	0	0
9	20 mg/kg	20.6	0	0	0	0	0
10	10 mg/kg	32.3	0	0	0	0	0
8	control in same barn	17.8	23.4	0	0	0	0

Although egg samples were examined without prior knowledge of treatment group, it became evident which hair samples were from sows in the treatment barn and which were from sows in the nearby farrowing barn. On hair samples from sows in the treated barn (Fig. 1 A & C), all eggs were ca. 2.5 cm from the base



FIGURE 1. *Haematopinus suis* eggs collected from hair samples 28 days after treatment with chlorpyrifos: A and C, eggs in treated barn; B, eggs from non-treated barn.

of the hairs, whereas from the non-treated barn eggs extended to the base of the hair (Fig. 1 B). Egg production had ceased on sows in the treated barn and as the hair grew eggs were extended further from the body. Eggs also showed a definite pattern as to whether they were hatched or unhatched. Those on the outer regions of the hair had hatched whereas those on the inner regions remained unhatched. The majority of these eggs were non-viable and in most instances a desiccated, nearly complete embryo was observed by identification of legs and tarsal claws.

The results of the egg samples are presented in Table II. Of the 129 eggs collected from untreated sows in the nearby farrowing barn, 12.4% were viable as compared to an overall viability of 0.58% of 689 eggs collected from sows in the test and control groups in the treatment barn. The eggs classified as viable

TABLE II. The condition of *Haematopinus suis* eggs taken from untreated and chlorpyrifos treated animals 28 days posttreatment, Fergus, Ontario, 1978.

Treatment	No. of Eggs	Percentage		
		Hatched	Desiccated	Viable
30 mg/kg	197	67.6	31.0	1.5
20 mg/kg	153	35.2	64.7	0
10 mg/kg	131	32.0	67.9	0
Checks inside barn	208	91.3	8.1	.04
Total	689	60.8	38.6	0.58
Checks outside barn	129	84.4	3.1	12.4

inside the treatment barn still contained some embryonic fluid but were 2.5 cm from the hair base and because of the location on the hairs were presumed to be ca. four weeks of age and thus of questionable viability. On treated animals, 30-68% of the eggs were unhatched and desiccated as compared to less than 10% of the eggs on non-treated animals. Although no nymphs, adult lice and only (.04%) one viable egg could be found on non-treated animals within the treatment barn, the percentage of unhatched desiccated eggs was considerably lower than that of treated animals; 8.1% as compared to 31-68%. This indicates that some eggs on non-treated animals were unaffected by insecticide vapours but that nymphs were destroyed once the eggs hatched.

Buchanan and Coles (1971) found 2% hatchability from eggs of cattle lice *Linognathus vituli* (L.) and *Damalinea bovis* (L.) when hair patches were sprayed with 250 ppm chlorpyrifos. Loomis *et al.* (1976) found similar results when chlorpyrifos was applied as a spot-on treatment to the backline of cattle. Three possible mechanisms exist by which chlorpyrifos reaches lice and their eggs. These include; 1) contact toxicity, as would be observed on whole body sprays of animals, 2) systemic activity as suggested by Loomis *et al.* (1976) and 3) fumigant action.

This study strongly suggests that at least part of the mortality resulting from a single spot-on treatment with chlorpyrifos was caused by fumigant action. With this type of application method, direct contact toxicity over the entire body of the animal is not possible. Although Claborn *et al.* (1968) showed residues of chlorpyrifos particularly in the fat of cattle for up to five weeks after treatment, it is believed that the systemic activity of chlorpyrifos did not cause appreciable louse mortality particularly against the eggs. The mode of action by which chlorpyrifos residues can reach eggs on relatively inert hairs is difficult to explain by systemic action.

Most registered products for control of cattle grubs aid in the reduction of louse populations but do not give complete control because eggs are unaffected by treatment. Systemic activity of chlorpyrifos does not affect *Hypoderma* spp. when applied as a whole body spray at a rate of 35 mg/kg (Drummond 1966) yet in this trial complete control of lice including eggs occurred at dosages of 30 mg/kg and less. Chlorpyrifos has been shown ineffective against *Sarcoptes scabiei suis* Gerlach when applied as a pour-on at 20 mg/kg (Galloway and Westwood unpublished). This would suggest complete louse control in this study cannot be explained by systemic action. Although chlorpyrifos has a moderate vapour pressure of 1.87×10^{-5} mm Hg at 25°C (Dow Chemical Co. 1965), Kenega *et al.* (1965) showed that the insecticide was sufficiently volatile to form residues on

surfaces of nearby objects. They found in laboratory studies that residues from vapours were sufficient to control houseflies and aphids 24 hr after exposure to chlorpyrifos vapours. This presents the possibility that control in this study was due to fumigant action. It also would explain the control of lice on untreated animals and agree with the observation of a strong insecticidal odor which persisted for at least four days following treatment.

These data provide additional evidence that chlorpyrifos is ovicidal and provides complete control of lice with a single low dose spot-on treatment, thus avoiding the necessity of follow-up treatments. The data also suggest the possibility of controlling lice on animals without actually treating the individual animals. This could have practical implications for control of lice or mites on poultry where large numbers of individual birds are present and individual treatment may be prohibitive.

Acknowledgments

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**THE EFFICACY OF SELF-APPLICATING DEVICES FOR CONTROL OF
THE FACE FLY, *MUSCA AUTUMNALIS* (DIPTERA: MUSCIDAE)
AND THE HORN FLY, *HAEMATOBIA IRRITANS* (DIPTERA: MUSCIDAE)
ON CATTLE NEAR GUELPH, ONTARIO¹**

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Abstract

Proc. ent. Soc. Ont. 110: 9-17 (1979)

The efficacy of several, self-applicating devices and insecticides in controlling the face fly, *Musca autumnalis* DeGeer, and the horn fly *Haematobia irritans* (L.) on cattle, was evaluated. The free-choice devices tested were the Injecto-Rub® oiler with 1% crotoxyphos and the Dr-Scratch® back rubber with 3% stirofos dust. A forced-use device, the Farnam Walk-Way® oiler containing Ciovap® (1% crotoxyphos and 0.25% diclorvos) and a combination forced-use and free-choice device, the Tox-O-Wik® beef oiler containing 1% malathion and 2.5% methoxy-chlor, were also evaluated.

Only the Tox-O-Wik® beef oiler provided a significant reduction in the populations of the face fly. Free-choice devices did not provide satisfactory control of the horn fly whereas forced-use and combination forced-use and free-choice devices provided excellent control of this insect.

Introduction

The face fly, *Musca autumnalis* DeGeer, is an introduced pest of cattle and horses in Ontario. Since its initial discovery in Nova Scotia (MacNay 1952), it has spread rapidly throughout North America such that, by 1970, it has been reported from the southern parts of all the provinces in Canada, and most of continental United States (Depner 1969; Smith and Linsdale 1969).

The face fly irritates cattle by feeding on lachrymal and nasal secretions. Maximum numbers occur in July and August and have been observed to be as high as 75 to 100 per animal (Wrich 1970). Although in North America, the face fly is believed to cause reduced milk-yields and weight gains (Teskey 1960), it is not considered a pest of economic importance in Europe (Benson and Wingo 1963). There is evidence that the face fly causes pinkeye in cattle (Brown and Adkins 1972) and transmits several species of *Thelazia* sp. (Spirurata: Nematoda) to the eyes of cattle and horses (Branch and Stoffolano 1974). Annual losses attributable to the face fly in the United States were estimated to be \$68 million from 1959 to 1961 and \$140 million from 1973 to 1975 (ARS National Research Program 1976).

Attempts to control the face fly on cattle have consisted of diets containing insecticides, aerial-spraying with ultra-low volumes of insecticides, and applying insecticides or repellents manually using devices such as oil cans, brushes and sprayers. These efforts have been generally unsatisfactory (Ode and Matthyse 1964; Dorsey *et al.* 1966; Kantack *et al.* 1967). Self-treatment, insecticide-applicating devices, primarily swing-type back rubbers, tank-type oilers, and dust bags, have been studied in forced-use and free-choice positions. Although the reductions in the face-fly populations have often been unsatisfactory, there have

¹ From a thesis submitted by L. A. Barlow in partial fulfillment of the requirements of the M.Sc. degree, University of Guelph, 1978.

been reports of self-applicating devices providing satisfactory reductions (Hair and Adkins 1965; Seawright and Adkins 1968; Poindexter and Adkins 1970; Kessler and Berndt 1971; Ronald and Wingo 1973).

The efficacy in controlling the face fly using several types of self-applicating devices was evaluated. These devices, with one exception, had not been evaluated before. The mop-type device had been tested, but not extensively (Wright 1971). The effects of these devices and insecticides on populations of horn fly, *Haematobia irritans* (L.), were also observed.

Materials and Methods

During the summers of 1975 and 1976, privately-owned cattle herds in the vicinity of Guelph were used to evaluate the self-applicating devices. Between two and five pretreatment counts of flies were taken on each of the test and the check (untreated) herds. The average distance between herds was approximately eight kilometers. Counts of flies on the check herds were made on the same days as counts of flies on the test herds. After the installation of the devices, usually in mid-July to early August, such parallel counts on the test and the check herds were continued for one to two months, at approximately weekly intervals. Fly-counts were usually made between 10:00 hr and 16:00 hr. The cattle were usually at least 30 m from farm buildings when fly-counts were made. The first author made all the counts during both summers.

In the counting procedure, individual animals were approached and the face flies on the face, on one side, and the horn flies on one side were counted. Occasionally, 7 x 35 binoculars were used to aid the counting. In 1975, attempts were made to count the flies on 20 animals. In 1976, the sample size was reduced to 15 animals.

For each day on which flies were counted, the mean number of face flies per face, per side, and the mean number of horn flies per side for each test and check herd were calculated. The differences between the check and the test means obtained on the same day were tested for significance by an APL T-test program. To remove the observed correlation between fly count means and variances, the raw data was transformed by $\log_e (c + 1)$ before the analysis. The variable c was the number of flies per animal. Two tailed T-tests were done on the differences between test and check means observed before the initiation of treatment. If the test means were less than the check means after the initiation of treatment, one tailed T-tests were performed. The significance level used was $p \leq .01$. This was done to keep the experiment-wise error at a minimum. Where reductions attributable to treatment occurred in the face-fly or horn-fly populations on cattle with access to the self-applicating devices, the percentage reductions of flies were calculated using a modified Abbott's formula (Henderson and Tilton 1955).

$$\text{Percentage reduction} = \left(1 - \frac{\text{TA}}{\text{TB}} \times \frac{\text{CB}}{\text{CA}}\right) \times 100$$

TA and CA were the grand mean numbers of flies on the test and the check herds, respectively, after the initiation of a treatment. TB and CB were the grand means before the initiation of a treatment. A grand mean was calculated by averaging the test or the check means obtained before or after the initiation of a treatment.

The devices tested were the Injecto-Rub® oiler (angle-type), the Dr. Scratch® back rubber, the Tox-O-Wik® beef oiler (combination forced-use and free-choice),

and the Farnam Walk-Way® oiler (mop-type). The Injecto-Rub® oiler consisted of an insecticide tank bolted to a post and attached to a steel cable which functioned as a rubbing element. The rubbing element was anchored at an angle to the ground. When cattle rubbed against the steel cable, a pumping device delivered the insecticide formulation to the cable. At each of two farms, the oiler was installed on the pasture near salt blocks and sources of water for the cattle. At a third farm, the oiler was installed inside a "loafing" shed which contained a supply of salt. The insecticide formulation used in these oilers was diesel fuel oil containing 1% crotoxyphos.

The Dr. Scratch® back rubber consisted of a hollow rubber cylinder suspended horizontally between two steel posts. The cylinder was attached to a plastic bag containing 3% stirofos dust. The dust was discharged from several small holes distributed along the lower surface of the cylinder when cattle rubbed against the latter. This device was installed on a pasture near salt blocks.

The Tox-O-Wik® beef oiler consisted of an angle-type rubbing element and an insecticide tank from which a rubber apron was suspended. The lower margin of this apron consisted of an inch-thick ring of canvas connected to the inside of the tank by a wick. The rubber apron was suspended above a rubber tub containing mineral supplement. The purpose of the rubber apron was to force cattle intending to feed on the supplement to brush their faces against the insecticide-saturated ring of canvas. The oiler was installed on a pasture near the barn and filled with kerosene containing 1% malathion and 2.5% methoxychlor.

The Farnam Walk-Way® oiler consisted of an insecticide tank from which a mop-like rubbing element was suspended. When the rubbing element was moved by cattle passing under it, small quantities of the insecticide were discharged into the element from the tank by a pumping device. The oiler was hung in the doorway to the milking parlour and filled with Ciovap® (1% crotoxyphos and 0.25% dichlorvos) such that the animals used it four times a day.

Once the Injecto-Rub® oilers, the Farnam Walk-Way® oiler in 1975, and the Dr. Scratch® back rubber were installed, they were kept on the farms for the entire summer. The cattle, which had access to the Farnam Walk-Way® oiler in 1976 and the Tox-O-Wik® beef oiler, were separated from their devices after 46 and 31 days respectively, to determine what effect this would have on the fly-populations.

Results

Free-choice Devices

The face fly and horn fly numbers on cattle with access to the free-choice, self applying devices are presented in Figs. 1 and 2. The number of face flies on the faces of cattle in two herds, each with access to an Injecto-Rub®, containing 1% crotoxyphos (Ciodrin®), were not significantly different from those on nearby check herds (Figs. 1a, c). Numbers of horn flies per side were significantly lower on the treated animals compared to controls on all sampling dates after the installation of the oiler (Fig. 1b, d). The reductions were 58% and 85% respectively.

The number of face flies per face on cattle with access to the Injecto-Rub® oiler, containing 1% crotoxyphos, installed in a loafing shed frequented by cattle was usually not significantly different from that of the check herd (Fig. 2a). There was an 84% reduction in the number of horn flies per side on the treated cattle

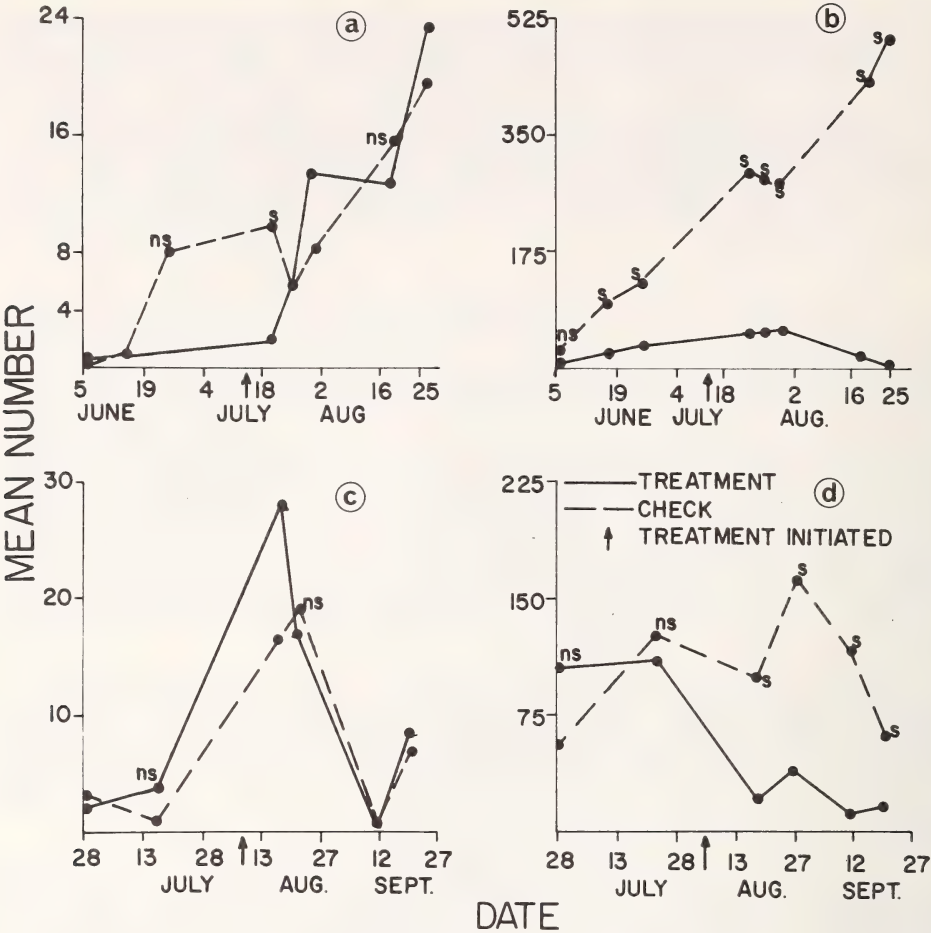


FIGURE 1. Fly populations on cattle with access to the Injecto-Rub® oiler containing 1% crotoxyphos, 1976. Mean number of *Musca autumnalis* per face (a) and *Haematobia irritans* per side (b) respectively, at first farm. Mean number of *M. autumnalis* per face (c) and *H. irritans* per side (d) respectively, at second farm. s = difference between means significant $p \leq .01$, ns = difference not significant.

(Fig. 2b). No significant reductions in face fly (Fig. 2c) or horn fly (Fig. 2d) numbers were observed on cattle with access to the Dr. Scratch® back rubber containing 3% stirofos (Rabon®) dust.

Combination Forced-use and Free-choice Device

There was no significant reduction in the number of face flies per face on cattle with access to the Tox-O-Wik beef oiler containing 1% malathion and 2.5% methoxychlor (Fig. 3a). An 86% reduction in the number of face flies per side was observed on test cattle while they had access to the oiler (Fig. 3b). Removal of the device was followed by an increase in the number of face flies per side. While the cattle had access to the device, the horn fly density was zero on every sampling date but the first (Fig. 3c). The overall reduction during this period was 85%. When the oiler was removed a small increase in the horn fly density on the test cattle to three per side, on September 3, was observed.

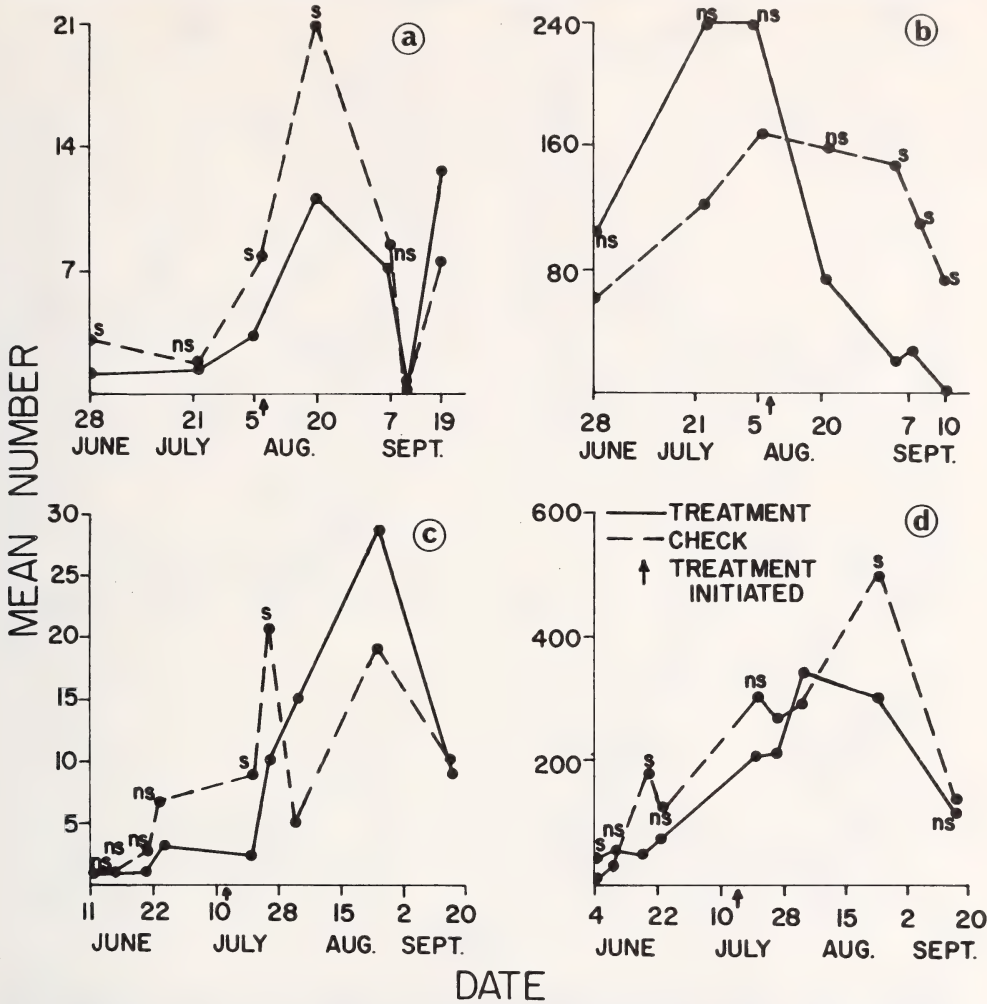


FIGURE 2. Mean number of *Musca autumnalis* per face (a) and *Haematobia irritans* per side (b) on cattle with access to an Injecto-Rub® oiler filled with 1% crotoxyphos and installed in a loafing shed, 1976. Mean number of *M. autumnalis* per face (c) and *H. irritans* per side (d) on cattle with access to a Dr. Scratch® back rubber containing 3% stirofos dust, 1976. s = difference between means significant at $p \leq .01$, ns = difference not significant.

Forced-use Devices

There was no significant reduction in the number of face flies per face of cattle using the Farnam Walk-Way® oiler, containing 1% crotoxyphos and 0.25% dichlorvos (Ciovap®, in 1975 and 1976 (Fig. 4a, c). Removal of the oiler in August 1976, was followed by a decrease in face fly numbers on test and check animals. This provided additional evidence that the device had no treatment effect.

In 1975 and 1976, there were 100% reductions in number of horn flies per side on cattle with access to the oiler (Fig. 4b and d). Removal of the oiler in 1976 was followed by an increase in the horn flies on the test cattle to levels that were not significantly different from the check animals.

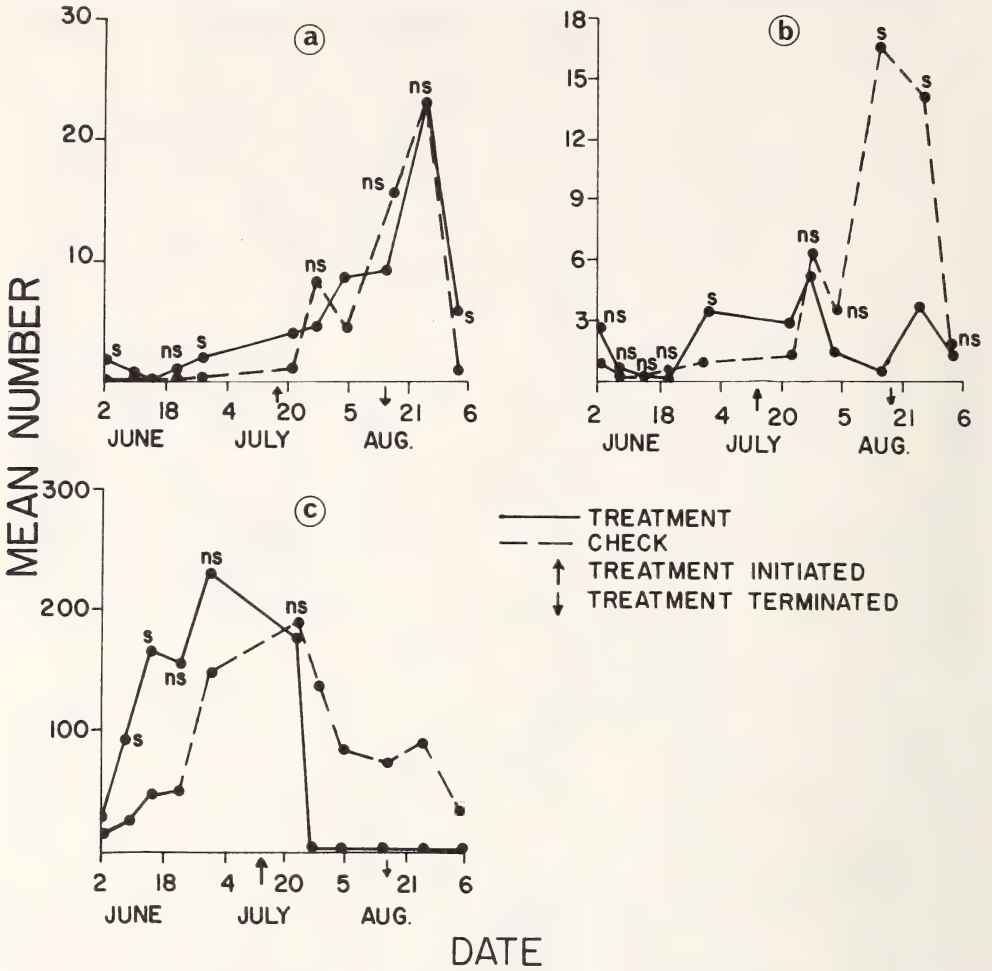


FIGURE 3. Mean number of *Musca autumnalis* per face (a), per side (b), and *Haematobia irritans* per side (c) on cattle with access to the Tox-O-Wik® beef oiler containing 1% malathion and 2.5% methoxychlor, 1976. s = difference between means significant at $p \leq .01$, ns = difference not significant.

Discussion

There were no significant reductions in the numbers of the face fly on the faces of cattle with access to the free-choice, combination forced-use and free-choice, and forced-use devices. A significant reduction occurred in the number of face flies on the sides of cattle with access to the combination forced-use and free-choice device, the Tox-O-Wik® beef oiler. However, the face-fly densities on the test cattle were almost always greater than 8-10 per face and 5-10 per animal, postulated as annoyance levels by Hansens (1961), DeFoliart (1963), and Hansens and Granett (1963). Therefore, the reduction in the face-fly numbers was not sufficient to prevent possible economic loss. There was no benefit to installing the angle-type oiler in a shed in which the cattle frequently congregated.

Benson and Wingo (1963), Kessler and Berndt (1971), Wright (1971) and Ronald and Wingo (1973) also found that free-choice and forced-use devices

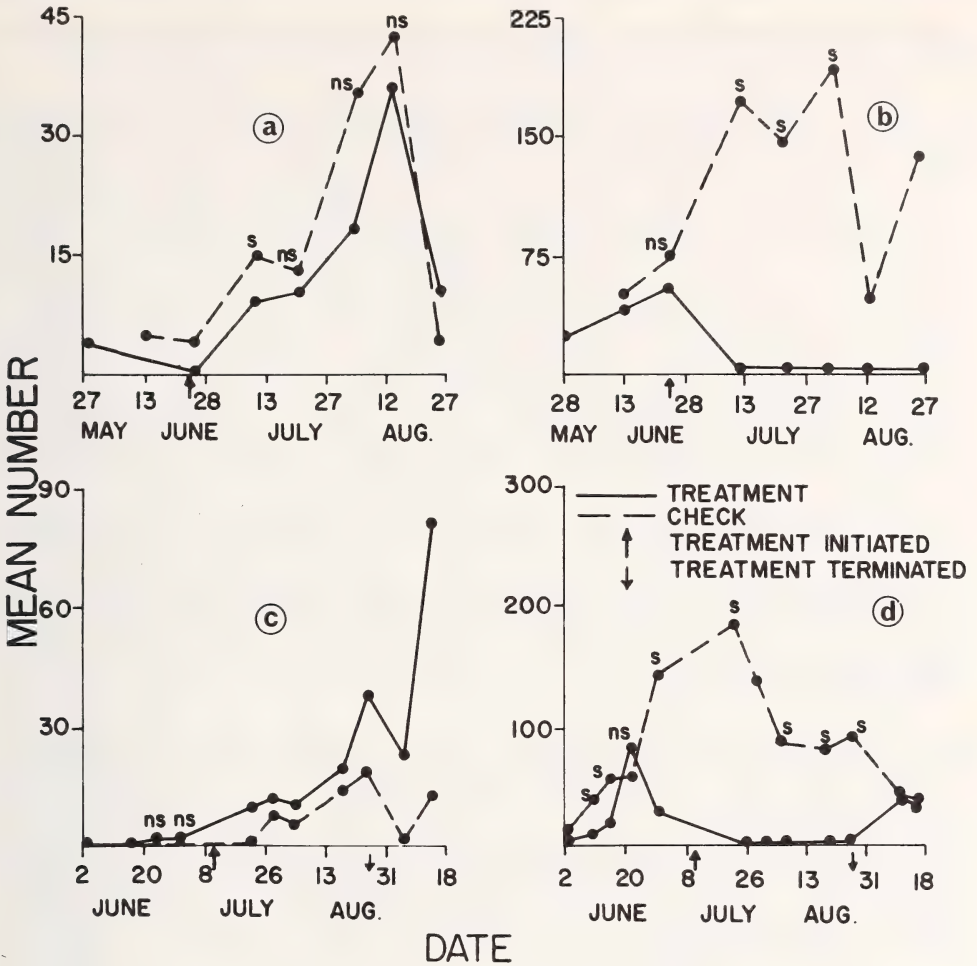


FIGURE 4. Fly populations on cattle using the Farnum Walk-Way® oiler containing 1% crotoxyphos and 0.25% dichlorvos. Mean number of *Musca autumnalis* per face (a) and *Haematobia irritans* per side (b) respectively, 1975. Mean number of *M. autumnalis* per face (c) and *H. irritans* per side (d) respectively, 1976. s = difference between means significant at $p \leq .01$, ns = difference not significant.

were ineffective in controlling the face fly. However, workers such as Dobson and Huber (1961), Hair and Adkins (1965), Turner (1965) and Poindexter and Adkins (1970) reported that free-choice and forced-use devices provided large reductions in the face-fly populations on the test cattle. Since a larger number of devices were tested in these four studies than in others including the present one, in which face-fly control was ineffective, area-wide reductions of the face-fly populations could have occurred.

There was excellent control of the horn fly on cattle using the forced-use and combinations forced-use and free-choice devices. The reductions in the horn-fly numbers were erratic on the herds with access to the free-choice devices. Where reductions occurred, namely on three herds with access to angle-type oilers, the average horn-fly densities were often greater than 10 or 50 per animal, postulated as economic injury levels by Dobson and Peterson (1963) and Morgan (1967).

Therefore, some economic loss due to the horn fly could have occurred on these herds.

Workers such as Kessler and Berndt (1971) also have noted that control of the horn fly was greater than that of the face fly on herds with access to self-applicating devices. This difference can probably be explained by several factors. The face fly is a highly dispersive insect (Ode and Matthyse 1967) and although flies which alight on treated animals may die, the continuous redistribution of flies prevents reduction of the population on a single herd. This phenomenon has been demonstrated in studies of feed-through insecticides (Hall and Foehse 1979). Face flies tend to congregate on the facial area which generally receives little insecticide since cattle tend to lower their heads when passing under a self-applicating device. Much of the insecticide that is applied to the face is probably removed by lachrymal and nasal secretions. These factors increase the difficulty of reducing the face-fly population on the faces of cattle. Horn flies are less dispersive than face flies and congregate on the back which cattle readily treat by passing under a self-applicating device. Furthermore, horn flies remain on cattle for greater periods of time, leaving only to oviposit or when disturbed.

The variation in the reductions of the horn-fly populations and, to a lesser extent, of the face-fly populations, could have been due partly to the different insecticides and insecticide formulations used in the devices. The reductions in the horn-fly populations on cattle using the forced-use and combination forced-use and free-choice devices were greater than those on cattle using the free-choice devices. This suggests that different frequencies of use of the devices by the cattle contributed to the variation.

The Dr. Scratch® back rubber containing 3% stirofos dust was the only device that did not provide a significant reduction in the horn-fly population on the test cattle. This is unusual since horn-fly populations are generally easy to control. The reason for this lack of control is unknown. On every sampling date after the initiation of the treatment, insecticidal dust was observed on the ground, at the base of the back rubber. On several occasions when cattle were observed using the device, dust was seen being applied to the backs of the animals. However, these were casual observations and an accurate determination of the frequency of use was not done.

Acknowledgments

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FLIGHT ACTIVITY OF THE GREEN PEACH APHID (HOMOPTERA: APHIDIDAE) DURING THE VEGETABLE GROWING SEASON AT HARROW AND JORDAN, ONTARIO

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Abstract

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Flights of the green peach aphid, *Myzus persicae* (Sulzer), were monitored from June to September, using suction traps at Harrow and yellow sticky traps at Jordan, Ontario from 1970 to 1976. In 1970-1975 the correlation coefficients between catches at these locations were significant ($P \leq 0.02$). In 1976 no inter-location correlation occurred and the unimodal curve of abundance found in other years at the two sites, did not occur. Unusually large flights in early 1976 at both locations could be attributed at least in part to warm weather in April and in the previous November, but the differences between the subsequent numbers trapped at Harrow and Jordan in 1976 could not be explained. The data are given in full for reference by subsequent workers studying alate aphid abundance and aphid-borne virus epidemiology in Ontario.

Introduction

Flying aphid populations have been monitored by suction traps at Rothamsted, England since 1947 (Johnson 1950) and data from a permanent network of suction traps, established in 1968, are used to issue weekly aphid bulletins and annual summaries (Taylor and French 1978). This network includes 20 traps in Great Britain and others in Holland and Denmark. The weekly aphid bulletins are used to advise growers of seed potato, sugar beet and field beans on the probability of virus damage or direct aphid injury if top killers or insecticides are not applied. Grower warning systems for green peach aphid (GPA), *Myzus persicae* (Sulzer) invasion of seed potatoes, based on yellow water trap catches, have been in use since the 1950's in Europe (Hille Ris Lambers 1955; Robert 1976). In Canada GPA trapping schemes for warning seed potato growers of seasonal aphid activity already exist in New Brunswick (MacGillivray 1977) and British Columbia (Weintraub 1977), also based on yellow water trap catches.

The abundance of flying GPA has been recorded at Harrow, Ontario, using suction traps and at Jordan, Ontario, using yellow sticky traps since 1967 and 1970 respectively (Elliott 1971; Kemp and Troup 1978). At Harrow the principal interest was in the likelihood and intensity of new infestations on vegetables starting at different times of year whereas at Jordan the data were used in studies on the epidemiology of stylet-borne, non-persistent viruses, particularly cucumber mosaic virus (CMV) in green peppers (*Capsicum frutescens* L.), which is vectored by the GPA.

The GPA is common on vegetable crops and tobacco in southern Ontario and would become more important, attracting more interest in monitoring, if there were an increase in susceptible crops grown, or in virus diseases. Aphicides could be withdrawn for environmental or health reasons or due to development of resistance, which appears to be happening (R. J. McClanahan, pers. comm).

The objective of this paper is to make available data on seasonal aphid flights in the peach and vegetable growing areas of southern Ontario. This may assist later workers in assessing whether their catches are unusually high or low and early or late. Furthermore, it is important to know if the activity of the GPA at opposite ends of the S.W. Ontario vegetable growing area are similar when considering the applicability to one site of conclusions drawn from the other. Harrow data prior to 1971 were previously reported (Elliott 1971). The Jordan data have not been published before.

The Harrow and Jordan sites are influenced by about 800 and 2,700 hectares of peach orchard respectively in the surrounding areas. These are early sources of aphids which are much less extensive in the counties between the sites. The growing season of 155-165 frost-free days and 3300 corn heat units at Harrow and Jordan also differs from that in the vegetable growing areas between them (<155 frost free days and 2900-3300 corn heat units).

Methods

Alate GPA were monitored at Harrow from April to November, 1970 to 1976 with two suction traps and procedures somewhat modified from those of Elliott (1971). A one-gallon reservoir was connected to the aphid collecting jar by PVC tubes to maintain sufficient ethyl alcohol in the jar for a week. Insects were removed from traps at weekly intervals and on the same day of the week as far as possible. When catches were large they were subsampled and the count of GPA in whole catches was calculated. Samples of the 1976 GPA were cleared, dehydrated and mounted on microscope slides by the method of Richards (1964) and examined under 100 X magnification. Lateral abdominal tubercles were counted to determine the origin of the unusually large early July catches by the method of Woodford and Lerman (1977).

The "Insectary" suction trap, located near the Harrow Research Station insectaries, was adjacent to vegetable plots and mowed grass to the S., continuous corn to the W. and farm buildings and houses to the N. and E. It caught insects flying 1 m above the ground (Elliott 1971).

The similar "Ridge Farm" suction trap was located on the Ridge Farm property of the Harrow Research Station, about 3.2 km S.E. of the insectary site. A peach orchard located to the E. and S. of this trap had been planted in 1969 and possibly exercised more influence on the catches each year as the trees grew. On the N. and W. side there was a small building and an irrigation pond with plots of vegetables further away on the N. side. Usually plant growth and farm operations start earlier at Ridge Farm, which is on Fox sandy loam soil, than at the insectary site which is on a finer sandy loam soil.

Estimates of the aerial populations of alate GPA at Jordan, Ontario were made from weekly catches on sticky traps located among unsprayed green bell pepper plots on the Pond Farm property of the Agriculture Canada, Vineland Research Station, immediately E. of the Jordan Harbour inlet on Lake Ontario. Traps were constructed from wooden stakes 90 x 7.5 x 2 cm, painted white and driven into the ground. A 16.5 x 7-cm yellow band encircled the stake 7.5 cm from the top. Clear cellulose acetate cards each with a 15 x 6.5 cm trapping surface were attached to the yellow band on either side of each stake. Tree Tanglefoot® was applied from an aerosol can to the clear acetate cards which were 40 cm above the soil surface. Two cards from each of 3 to 6 traps were collected weekly, usually from the first week in June to the last week in September, examin-

ed and alate GPA counted. The average catch of GPA/card/week was used for correlation analysis with the suction trap counts from the Harrow sites on the closest dates.

Degree-day accumulations based on a 10° C threshold (DD10) were calculated from the formula in Kemp and Troup (1978), using daily maximum and minimum temperatures. Hours of sunshine were recorded with a Stokes Campbell sunshine recorder.

Results

Annual Patterns of Flight Activity

The same general pattern of flight activity occurred each year at Harrow at both sites in the years 1970-75 (Tables I and II). The first alate aphids were caught in June and numbers increased to a peak, usually in August but once in late July. By October, flight activity had virtually ceased. However in 1976 they were first caught in May with 2, 13 and 35 caught on 17, 24 and 31 May respectively at the Ridge Farm site (not shown in Table II). The peak numbers for the year 1976 occurred in the first 2 weeks of July, when catches were low in other years. Catches then became subnormal with no August peak, only approaching normal in late September.

Numbers caught/card/week at Jordan in 1970-75 usually exceeded numbers caught/suction trap/week at Harrow (Table III). Numbers were low in June, increasing to a seasonal peak in August (once in July). The year 1976 was exceptional at Jordan with relatively high catches in June, not increasing as rapidly in July as in other years and not reaching a peak until mid September. 1976 was thus unusual at both locations but unique at Harrow and also quite unlike any year when both suction traps were operating from 1969 to 1978 (Elliott 1971 and unpublished).

In May and early June 1976, 77-80% of the alate aphids captured at Harrow were fundatrigeniae (migrants from peach colonies) according to the criterion of Woodford and Lerman (1977), which is based on the number of lateral abdominal tubercles. In late June, 15% were fundatrigeniae and this declined to 2% by July with the rest of these large July catches being alienicolae (migrants from secondary hosts). The alate aphids forming this July peak were thus at least one generation removed from those in peach orchards. Colonies were easily found in well-kept peach orchards in Essex county in June 1976 and prompted sufficient enquiries from peach growers to justify a recommendation on control measures (Fisher 1976). No enquiries about the GPA on peach were received at Harrow in the other years of this study.

Differences Between 1976 and Other Years

DD10 accumulations prior to the early peaks of alate aphids in 1976 were not unusual except in April when >2X the mean for 1970-1975 occurred at Harrow and Jordan (Table IV). The DD10 accumulation in November 1975 exceeded the mean for 1969-1974 by >6X and >7X at Harrow and Jordan respectively. As would be expected, the sunshine hours in April 1976 and November 1975 were also higher than in most other years, although not as high as the DD10 accumulation would lead one to expect. Thus the overwintering populations in 1975/76 were favoured by warm weather during mating and oviposition in the fall and during development of the eggs on peach in the spring. The numbers of

TABLE I. Number of alate green peach aphids taken in the suction trap each week ending on the day shown (Insectary site, Harrow, Ontario).

Month	Day	Aphids			Day	Aphids				Day	Aphids
		1970	1971			1972	1973	1974	1975		
June	4	2	(1) ^a		6	(0)	1	(0)	(0)	7	(14)
"	11	5	(1)		13	(0)	0	(0)	(0)	14	(3)
"	18	5	0		20	0	0	(0)	0	21	0
"	25	1	2		27	0	0	1	0	28	6
July	2	3	3		4	5	1	0	4	5	31
"	9	3	1		11	7	3	4	0	12	172
"	16	7	3		18	35	0	1	4	19	11
"	23	5	9		25	103	8	0	4	26	2
"	30	45	84								
August	6	13	375		1	66	17	10	52	2	2
"	13	72	267		8	24	104	31	8	9	0
"	20	61	355		15	59	110	38	20	16	3
"	27	38	177		22	66	6	28	12	23	17
					29	12	58	11	4	30	5
September	3	20	66		5	3	13	2	4	6	1
"	10	23	11		12	(6)	(0)	2	0	13	3
"	17	(1) ^a	4		19	(25)	(0)	10	0	20	10
"	24	(8)	(4)		26	(26)	(2)	8	0	27	5
October	1	(6)	(3)		3	(13)	(0)	3	0	4	(20)

^a Figures in brackets were not used in correlation calculations, since corresponding data for Jordan were not available.

TABLE II. Number of alate green peach aphids taken in a suction trap each week ending on the day shown (Ridge Farm site, Harrow, Ontario)

Month	Day	Aphids			Day	Aphids			Day	Aphids	1976
		1970	1971			1972	1973	1974			
June	4	2	(0) ^a		6	(0)	6	(0)	7	(197)	
"	11	4	(0)		13	(0)	2	(4)	14	(111)	
"	18	1	0		20	0	1	2	21	43	
"	25	1	0		27	3	5	4	28	80	
July	2	6	0		4	6	1	4	5	709	
"	9	2	0		11	9	5	4	12	660	
"	16	0	0		18	22	3	3	19	^b	
"	23	7	8		25	25	2	8	26	1	
"	30	4	95								
August					1	50	18	4	2	8	
"	6	44	180		8	14	101	40	9	1	
"	13	64	357		15	23	289	72	16	19	
"	20	100	366		22	86	42	32	23	0	
"	27	22	143		29	33	52	12	30	12	
September											
"	3	24	57		5	5	8	16	6	4	
"	10	27	21		12	(8)	(0)	20	13	0	
"	17	(7) ^a	5		19	(0)	(4)	16	20	8	
"	24	(6)	(3)		26	(0)	(12)	8	27	0	
October	1	(6)	(6)		3	(0)	(0)	2	4	(8)	

^a Figures in brackets were not used in correlation calculations, since corresponding data for Jordan were not available.
^b No catch due to motor failure.

TABLE III. Number of alate green peach aphids taken per yellow sticky card each week ending on the day shown (Jordan, Ontario)

Month	1970		1971		1972		1973		1974		1975		1976	
	Day	Aphids	Day	Aphids	Day	Aphids	Day	Aphids	Day	Aphids	Day	Aphids	Day	Aphids
June	5	0					5	2						
"	12	0					12	5						
"	19	0	21	6	21	22	19	3	18	2	18	0	23	23
"	26	0	28	4	28	2	26	6	25	3	24	1	30	21
July	3	0	5	54	5	24	3	16	2	2	2	4		
"	10	13	12	296	12	51	10	12	11	35	9	4	7	30
"	17	34	19	59	19	93	17	46	16	16	16	7	14	33
"	24	68	26	191	26	167	24	121	23	69	23	25	21	41
"	31	125					31	208	30	110	30	117	28	12
August			3	195	2	130								
"	7	140	9	168	9	291	7	230	6	107	6	81	4	36
"	14	225	16	311	15	413	14	527	13	41	13	122	11	56
"	21	175	23	344	22	299	21	486	20	78	20	101	18	65
"	28	125	30	179	29	176	28	434	27	89	28	49	25	71
September													31	100
"	4	150	7	200	6	173	4	202	3	71	4	9		
"	11	105	14	293			10	19	10	19	10	5	7	61
"			20	42			17	33	17	33	17	1	15	220
"							24	18	24	18	24	5	22	150
October							1	8			1	7	29	14

TABLE IV. Weather data and fall catches of alate green peach aphids in (1970-1975) and 1976.

Factor	Period	Location	1970 - 1975		1976 ^a
			Mean $\pm$ s.e.	Range	
DD10	April ^a	Harrow	30.5 $\pm$ 9.2	6.9 - 60.3	67.5
	"	Jordan	19.5 $\pm$ 7.3	2 - 46	54.0
"	Previous Nov. ^a	Harrow	6.8 $\pm$ 2.4	2.2 - 15.3	46.7
	"	Jordan	6.4 $\pm$ 1.4	0.4 - 9.5	45.4
Sunshine Hours	April	Harrow	182.3 $\pm$ 6.8	157.8 - 201.4	229.9
	"	Jordan	214.5 $\pm$ 7.8	194 - 249	285.0
	Previous Nov.	Harrow	117.3 $\pm$ 21.6	41.7 - 182.4	119.4
	"	Jordan	70.5 $\pm$ 5.9	49.5 - 93.7	91.7
Female alate (GPA) trapped	Previous Sept.-Nov.	Harrow	180 $\pm$ 52	54 - 353	80
Male alate (GPA) trapped	"	"	32 $\pm$ 6	16 - 48	39

^a April observations are from (1970-1976) but Fall observations are from (1969-1975), since a relationship is proposed between the number of peach migrants and weather in the *previous* November and April.

males and females flying to peach trees in the fall were not exceptionally high (Harrow data only, Table IV).

Correlation Analyses

The correlation coefficients between weekly catches at both Harrow suction trap sites and on cellulose acetate sticky cards at Jordan were significant at $P \leq 0.02$ in 1970-1975 (Table V). Catches at the Harrow sites were more closely correlated with each other in most years, and when all the years were amalgamated, than catches from either site were with those from Jordan. The combined data from the Harrow sites (using $\log_{10}$ W Harrow site catches + 1) produced correlation coefficients with Jordan catches which were intermediate between the correlation coefficient of Jordan with each Harrow site catch separately in 1972 and 1973 or higher than those between Jordan and the two sites separately in 1970, 1971, 1974 and 1975.

There was no correlation between the numbers caught at the Harrow locations and the Jordan site in 1976. This can be attributed to the exceptionally high early July catches and the very low August and September catches at Harrow. In addition, the correlation between the two Harrow sites was lower in 1976 than in other years, although still significant ($P \leq 0.05$).

Regression Equations

Regression equations treating the Jordan catches as the dependent variable i.e. $y = \log_{10}$ (Jordan catch + 1) and $x = \log_{10}$ (Σ Harrow catches + 1) for the years 1970-75 were not very similar, even though the correlation coefficients were high.

The regression coefficient ranged from 0.39 to 1.52 in the years 1970-1975. The intercept i.e. $\log_{10}$ (Jordan catch + 1) when combined Harrow catches = 0)

TABLE V. Coefficients of correlation between Jordan Station yellow sticky trap catches and Harrow (Insectary) and Harrow (Ridge Farm) suction trap catches and with the sum of the two Harrow sites and between the two Harrow sites, using $\log(n + 1)$ transformation.

Years	Correlation Coefficients (r)				Degrees of Freedom
	Insectary v. Jordan Stn.	Ridge Farm v. Jordan Stn.	Ridge Farm + Insectary v. Jordan Stn.	Insectary v. Ridge Farm	
1970	.818**** ^a	.690**	.839***	.746***	13
1971	.645**	.668***	.674***	.969***	12
1972	.786***	.680***	.735***	.891***	10
1973	.836***	.750***	.828***	.866***	12
1974	.621**	.595**	.698***	.725***	14
1975	.865***	.862***	.891***	.783***	14
1976	.005 NS	-.236 N.S.	-.225 N.S.	.548*	13 ^b
(1970 - 6)	.683****	.571***	.661***	.778***	99
(1970 - 5)	.737****	.685****	.745****	.842****	85 ^b

****, ***, **, * and N.S. = Significant at $P \leq 0.001$, 0.01, 0.02, 0.05 and Not Significant, respectively.
^aone week of data missing at Ridge Farm in 1976, $\therefore$ one less D.F. in correlations involving Ridge Farm site.

ranged from -0.69 to 1.41 . Combined data for the 6 years with good agreement between Harrow and Jordan (1970-1975) gives the equation $y = 0.81x + 0.56$, whereas the inclusion of the disruptive 1976 data gives the equation $y = 0.67x + 0.73$, implying 3 to 4 alate aphids per card would be caught at Jordan when none was caught at Harrow, during the season of the year when these observations would normally be taken.

Discussion

The generally larger catches on cellulose acetate sticky traps at Jordan relative to suction traps at Harrow are not necessarily due to a difference between methods, because differences in efficiency of the methods could be evaluated only by using both methods at the same site over several years.

Significant agreement between the areas for six years is very deceptive since it is completely absent in the 7th year. Monitoring GPA activity at a few sites in the S.W. Ontario vegetable growing area is likely to leave sites where the trend is opposite to that observed at monitoring sites. The local demand for information, and the staff and facilities available should determine how much is done and extrapolations should not be made.

The difference between 1976 and the other years in the initial population of alate aphids is fairly well explained by the meteorological factors used by Kemp and Troup (1978) for predicting CMV, but the difference in trend at Harrow and Jordan which occurred in July 1976 is not. The population flying to peach trees in Fall 1975 was not exceptionally high but conditions for sexual reproduction were favourable. The 1976 migration from peach was heavy and early but thereafter differences occurred between Harrow and Jordan which we have not identified. Alate aphids of the July peak at Harrow were morphologically distinct and therefore ≥ 1 generation removed from those produced by colonies on peach and could either be their descendants or migrants from outside the immediate area.

Taylor (1977) presents evidence that Watson's (1966) success in forecasting sugar beet yellowing viruses for several British sugar beet areas from the weather at Rothamsted is possible because of the position of Rothamsted between the source of early GPA migrants from overwintering areas, and the sugar beet growing areas. This implies that Jordan and Harrow, where the GPA overwinters on peach, are suitable areas for GPA monitoring related to virus epidemiology and should be relevant for such research in future years, although the difference is that early migrants in Britain are principally *alienicolae* from weed and crop hosts (Woodford and Lerman 1977).

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EFFECT OF PERMETHRIN, CYPERMETHRIN AND CHLORPYRIFOS ON LOUSE POPULATIONS OF BEEF CATTLE

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Abstract

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The following insecticides were evaluated for louse control: permethrin as a dust at 142 and 284 mg active ingredient (ai)/animal and as a spray at *ca.* 100 and 200 mg ai/animal, cypermethrin as a pour-on at 375 mg ai/animal, and chlorpyrifos as a spot-on at 20 mg/kg. Louse populations were primarily *Bovicola bovis* (L.) (>90%) and low numbers of *Linognathus vituli* (L.) and *Haematopinus eurysternus* (Nitzsch). All treatments initially reduced populations, but they recovered after the permethrin 142 mg ai/animal dust and both spray applications so as to warrant retreatment. The permethrin 284 mg ai/animal dust, cypermethrin and chlorpyrifos treatments all effectively reduced populations for at least 49 days after treatment.

Introduction

Cattle lice of economic importance in Canada include the short-nosed cattle louse, *Haematopinus eurysternus* (Nitzsch); long-nosed cattle louse, *Linognathus vituli* (L.); capillate louse, *Solenopotes capillatus* Endelein; and the cattle biting louse, *Bovicola bovis* (L.). In Ontario, Teskey (1960) reported that lice were present on 43 of 70 herds examined with *B. bovis* the most abundant followed by *L. vituli*, *S. capillatus* and *H. eurysternus*.

Lice have been reported as major pests of cattle causing low vitality, reduced growth and constant irritation (Matthysse 1946; Kemper *et al.* 1948). Recent studies (Collins and Dewhirst 1965; Rich 1966; Cummins and Tweedle 1977) have indicated that natural louse populations rarely attain levels that cause economic losses. Despite this, many producers in Ontario treat all their cattle to ease the irritation and prevent potential weight gain reductions caused by lice.

Populations of lice attain maximum levels during mid-winter in temperate North America resulting in the initiation of control measures in January or February (Wright 1976). Products currently recommended for control in Ontario often require two applications about two weeks apart (Anonymous 1979). The second application is required because most insecticides neither affect louse eggs nor have sufficient residual activity to destroy newly emerged nymphs which may hatch 7-10 days after the initial treatment. These nymphs are a source of reinfestation and require a second treatment before new eggs are laid. A control measure requiring only one treatment would increase convenience and decrease cost.

The study reported herein was undertaken to determine; a), the efficacy of permethrin, cypermethrin, and a new formulation of chlorpyrifos for louse control; and b), the number and type of applications for the most efficient control. Weight gains of treated and control animals were also monitored.

Materials and Methods

Animals used were bull calves and heifers of mixed crossbreeds weighing 200 to 400 kg. All harbored natural louse populations and had no prior history of insecticidal treatment. Animals were maintained on a large feedlot near Guelph, Ontario and were individually identified by numbered ear tags.

The insecticides, formulations, application rates and number of animals treated are presented in Table I. Application rates were those recommended by the manufacturers. Treatments for tests one to three were performed on 9 January 1979 while treatments for tests four to seven were performed on 16 January 1979. Dust formulations were individually weighed and then shaken onto both sides and backline of the cattle. The permethrin spray was mixed from a 25% active ingre-

TABLE I. Insecticides evaluated and dosages applied for control of cattle lice, Guelph, Ontario, 1979.

Insecticide	Test Number	Formulation	Application Rate (ai) ^a		Number of Cattle Treated
			1st Treatment	2nd Treatment	
Permethrin	1	WL 43479 0.25% ai dust ^c	284 mg/animal	not required	8
	2	Ectiban® 0.25% ai dust ^d	142 mg/animal	142 mg/animal	8
	3	Ectiban® 0.0125% ai spray ^d	100 mg/animal	200 mg/animal	7
Cypermethrin	4	WL 43467 0.25% ai pour-on ^c	375 mg/animal	not required	7
Chlorpyrifos	5	Dursban®44 43.2% ai spot-on ^e	20 mg/kg	not required	8
	6	Dursban®44 43.2% ai spot-on ^e	20 mg/kg	not required	3(1) ^b
	7	Dursban®44 43.2% ai spot-on ^e	20 mg/kg	not required	2(2) ^b

^a Active ingredient.

^b Number in parentheses refers to the number of non-treated cattle kept in the same pen as the treated cattle.

^c Shell Canada Ltd.

^d ICI Americas Ltd.

^e Dow Chemical of Canada Ltd.

dient (ai) emulsifiable concentrate (EC) and water, and applied to wet the entire animal using a Chapman R #135 compressed air sprayer. The mean volume of spray applied to each animal was 0.8 l for the first treatment and 1.6 l for the second treatment. The application rate was doubled for the second treatment in an attempt to increase efficacy. Cattle in tests two and three were retreated 35 and 21 days posttreatment respectively when louse numbers began to increase significantly. The cypermethrin pour-on was mixed from a 10% ai EC and water, and applied along the backline. The chlorpyrifos (43,2% ai) ready-to-use spot treatment was applied to the centre of the backline using a plastic squeeze applicator.

Cattle in tests one to four were held in a heated barn with three or four animals per pen. All cattle in each pen received the same treatment. Plywood on the sides of the pens prevented physical contact between treated animals. Ten

control animals were held in the same barn with a vacant pen between treated groups and the controls. The same cattle were used as controls for tests one to four, however, due to the one week delay in initiation of test four, louse indices of control animals for test four were not made on the same date as those for tests one to three. All cattle were fed a full ration diet of 70% corn silage, 27% cob meal, 2.5% soybean and 0.5% mineral supplement.

Cattle used in tests five to seven were held in unheated, open-faced barns with four animals per pen. All treated animals were heifers with eight bull calves located in another barn but under the same conditions used as controls. Heifers were fed as in treatments one to four, while bull calves were fed 50% corn silage and 50% pelleted ration containing 13% protein. In tests six and seven untreated animals were held with chlorpyrifos treated cattle to determine if all animals in a herd had to be treated to provide adequate control throughout the herd. Only untreated cattle in tests six and seven were weighed and assayed for lice. Louse numbers on treated animals in tests six and seven were assumed to respond similarly to those of chlorpyrifos treatment five.

Louse populations were monitored using a louse index based on the total number of lice found in 52 hair-parts (*ca.* 3 cm long) per animal (Shemanchuk *et al.* 1963). The 52 hair-parts were distributed as follows: three tail head, six backline, six side, two ear and six brisket on each side of the animal and six along the crest of the neck. Each animal was held in a squeeze and counts done immediately before treatment and at 7, 21, 35 and 49 days posttreatment except that the 35 day posttreatment counts for tests five to seven were not performed. Cattle were weighed to the nearest kg prior to each louse assessment.

The average weight gain per animal per day over the entire study period was used as the data for a one-way analysis of variance. Statistical analyses were not performed on tests six and seven due to insufficient sample size. A modified Abbott's formula was used to determine the percent reduction of louse populations resulting from treatments (Henderson and Tilton 1955).

Results and Discussion

Three species of lice were found on the cattle: *B. bovis*, *L. vituli* and *H. eurysternus*. *B. bovis* comprised >90% of the lice with the greatest densities (>70 lice/hair-part) along the crest of the neck and backline. *H. eurysternus* and *L. vituli* were most common along the brisket with maximum densities of *ca.* 10 lice/hair-part. The lowest densities of lice were along sides and tail heads.

Populations of lice on the control animals (Table II) for tests one to four attained maximum numbers between 14 and 21 days after the initiation of the first tests (late January) and declined thereafter. Louse populations on the control cattle for tests five to seven declined steadily throughout the experiment. The increase in lice in mid-winter and subsequent decline is typical of louse populations although the cause of these fluctuations is not fully understood. Jensen and Roberts (1966) attributed *S. capillatus* population fluctuations to be dependent upon air temperatures while Lewis *et al.* (1967) attributed major fluctuations to host grooming.

Permethrin Tests

The permethrin treatments initially reduced louse numbers by 85 to 95%. The lice remaining seven days posttreatment in tests one and two were primarily *L. vituli* and some *H. eurysternus* located on the brisket. The survival of these lice

was probably due to insufficient dust reaching the brisket. Test three initially reduced the numbers of lice over the entire body, including the brisket. However, populations subsequently increased, apparently due to recruitment from *B. bovis* eggs located along the crest of the neck. As a result of the significant increase in tests two and three, animals were retreated 35 and 21 days posttreatment respectively. These retreatments again initially reduced populations but they increased rapidly again in test three.

The most efficient and effective of the permethrin treatments was test one (284 mg 0.25% ai dust/animal), requiring only one treatment to produce >95%

TABLE II. Effect of permethrin (tests 1 to 3) cypermethrin (test 4) and chlorpyrifos (tests 5 to 7) on louse populations and weight gains in cattle, Guelph, Ontario, 1979.

Test Number	Mean Louse Index Days Posttreatment					Mean Weight Gain (kg/animal/day)
	0	7	21	35	49	
1	190.8 (21.6) ^a	9.5 (4.2)	15.1 (5.4)	20.7 (9.4)	17.6 (7.9)	1.06 (0.07)
2	222.0 (38.3)	9.1 (3.5)	47.8 (9.6)	63.0 ^b (13.3)	3.1 (1.9)	1.15 (0.06)
3	153.7 (20.3)	24.8 (15.7)	87.7 ^b (16.3)	15.4 (6.0)	63.6 (35.1)	1.12 (0.04)
Controls (tests 1-3)	79.6 (11.5)	119.8 (16.6)	191.4 (31.9)	140.3 (19.3)	85.5 (14.7)	1.19 (0.05)
4	277.5 (31.9)	0 (—)	1.4 (1.0)	2.3 (1.2)	7.0 (5.6)	0.95 (0.09)
Controls (test 4)	119.8 (16.6)	258.2 (48.4)	224.1 (38.3)	106.2 (19.4)	61.4 (24.4)	1.16 (0.05)
5	120.1 (30.9)	0 (—)	0 (—)	NC ^c	0 (—)	1.14 (0.08)
6	112.0 (—)	0 (—)	0 (—)	NC ^c	0 (—)	1.06 (—)
7	180.0 (119)	0 (—)	0 (—)	NC ^c	0 (—)	1.17 (0.17)
Controls (tests 5-7)	69.6 (10.1)	55.0 (14.6)	61.8 (18.3)	NC ^c	32.6 (6.9)	1.27 (0.11)

^a All bracketed numbers are standard errors.

^b Retreated immediately after count.

^c Not counted.

reductions throughout the experiment. This residual efficacy was due to either a direct ovicidal action, or residual contact toxicity to first-instar nymphs shortly after hatching. Test two was less efficient requiring two treatments and, because of the lower application rate, had little residual efficacy. Test three was the least efficient and effective requiring two spray applications with little residual efficacy even after the second treatment at the higher rate. In addition, most producers would be adverse to soaking their animals in mid-winter if other materials were available.

Cypermethrin Tests

The cypermethrin treatment caused a 100% reduction in lice seven days post-treatment with only slight recovery by the end of the experiment. Those lice present after treatment were mainly *L. vituli* and a few *H. eurysternus* located on the brisket. The residual efficacy may be due to ovicidal action, residual contact or systemic toxicity.

Chlorpyrifos Tests

The chlorpyrifos treatment (test five) caused a 100% reduction in louse numbers with no recovery. This residual efficacy was similar to that reported by Buchanan and Coles (1971) and Loomis *et al.* (1976) in New Zealand who used spray and spot-on chlorpyrifos formulations against *L. vituli*. Both studies reported that the residual efficacy was due to an ovicidal effect that eliminated reinfestation from hatching eggs.

Tests six and seven showed 100% reductions in louse populations on the untreated cattle when held with treated animals. This transfer of insecticide between cattle may have been from rubbing and/or a fumigant action. A similar phenomenon suggestive of fumigant action has been reported for *Haematopinus suis* (L.) (Surgeoner in press). The fact that not all animals need be treated may result in substantial savings in time and money required for louse control. These data indicate that the spot-on formulation of chlorpyrifos is efficient and effective requiring one application to produce 100% residual efficacy with neither mixing nor significant wetting of the cattle required.

Effect on Weight Gain

Although these trials were designed to evaluate the efficacy of insecticides, mean daily weight gains of cattle in the trials were also determined (Table II). The weight gain data are confounded as animals of both sexes were used, rations for some controls were different and housing conditions varied. Recognizing these variables, it should be noted that statistical analyses showed no significant differences between weight gains of treated and untreated animals.

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**DISTRIBUTION OF
MICROCTONUS AETHIOPOIDES,
A PARASITOID OF THE
ALFALFA WEEVIL (COLEOPTERA: CURCULIONIDAE) IN ONTARIO¹**

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Abstract

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Microctonus aethiopoides Loan, a bivoltine European parasitoid of the adult alfalfa weevil, *Hypera postica* (Gyll.), has become established throughout southern Ontario. A detailed survey of 41 counties in 1979 showed that incidence of parasitism caused by the spring generation of *M. aethiopoides* ranged from 13 to 92% and averaged 60. Dispersal in Ontario has been the result of recolonization from the United States. Reasons for its more rapid natural spread in Ontario are postulated.

Introduction

The braconid *Microctonus aethiopoides* Loan is a potentially important biological control agent of the alfalfa weevil, *Hypera postica* (Gyll.), in Ontario. Unlike other parasitoids of the weevil, this species attacks the adult stage. Hence, it enjoys a distinct advantage in that it is not forced to compete directly with *Entomophthora phytonomi* Arthur, a highly contagious disease organism that kills the weevil larvae and cocooned stages during recurrent epizootics (Harcourt *et al.* 1974, 1977).

M. aethiopoides has two generations a year (Abu and Ellis 1976). The adults of the first brood attack the overwintered weevils in the spring during the period of oviposition. Those of the second brood attack the new generation of adults in the summer before they leave the field. Both sexes are sterilized and subsequently killed by the parasitoid when it emerges. The second generation of the parasitoid passes the winter as an immature larva inside the hibernating host. Its general biology has been outlined by several authors, e.g., Loan and Holdaway 1961, Neal and Bickley 1971, Van Driesche and Gyrisco 1979.

Of European origin, *M. aethiopoides* was first introduced into the eastern United States in 1957 and 4 years later was firmly established in New Jersey (Day *et al.* 1971). Through successive recolonization and natural dispersal, the braconid is now present in at least 14 eastern states (Dysart and Day 1976).

M. aethiopoides was first released in Ontario in 1970 and 1971 (Williamson 1971, 1972) and recoveries were made one or two years later at five widely separated points across the Province (Dysart and Day 1976). Surveys in 1973 and 1974 by Abu and Ellis (1976) suggested that the parasitoid was slow to spread but in 1975 intensive sampling at two release sites by these same authors revealed high levels of parasitism. In long-term study plots in the Bay of Quinte area, its impact was felt for the first time in 1978 when populations of summer

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adult weevils were heavily attacked. This and numerous inquiries from extension personnel prompted us to determine the distribution of *M. aethiopoides* in southern Ontario.

Materials and Methods

During the spring of 1979, overwintered weevils subject to attack by adults of the first brood were collected from alfalfa fields in each county of southern Ontario. To ensure that larval stages of the parasitoid were present, samples from all areas were collected between 140 and 170°D >9°C. Sampling began in southwestern Ontario on May 28 and was completed progressively later across the Province. The samples were taken with a standard 38 cm sweepnet and 200 to 1000 sweeps, each consisting of a single sweep of the net through approximately 180°, were taken at each of 85 locations in 41 counties. As a rule, 2 sites were sampled per county (Fig. 1).

The adult weevils were taken to the laboratory, placed in cages on a screened platform (Loan and Holdaway 1961), and held for a minimum of 4 weeks. Emerging larvae dropped through the mesh and pupated in a layer of glass wool.

Results and Discussion

A total of 4,617 weevils were taken in 35,000 sweeps and numbers/100 sweeps ranged from 0.2 to 78. Table I shows that the parasitoid was present in every county and at all sites sampled. Incidence of attack ranged from 13 to 92%, averaging 60.

These levels of parasitism are comparable to those reported for the spring generation of *M. aethiopoides* in the northeastern United States (Brunson and Coles 1968, Dysart and Day 1976, Van Driesche and Gyrisco 1979). However, in Ontario levels of parasitism for the summer generation have generally been higher (Abu and Ellis 1976, Harcourt and Guppy unpublished). In the northeastern U.S. the adult weevils move from the field to aestivate soon after emergence from their cocoons (Blickenstaff *et al.* 1972). However, in Ontario dispersal from the field is delayed by cooler weather (Surgeoner and Ellis 1976) and in some years the weevils remain to feed for a considerable length of time. In eastern Ontario this period can extend for up to 6 weeks. This delay effectively increases the exposure time to the parasitoid and improves the chances of its survival. Furthermore, delayed dispersal and subsequent higher levels of parasitism would tend to enhance its rate of spread since the host weevil disperses freely before and after hibernation.

It is too early to judge what impact *M. aethiopoides* will have on population trends of *H. postica* in Ontario. Previous to 1978, numbers of the weevil oscillated under control of the fungus disease about a level close to the economic threshold. However, this organism is not entirely compensating in its action and periodic population eruptions, mostly of a local nature, have occurred each year. It is hoped that *M. aethiopoides* will damp these oscillations by killing a significant proportion of those individuals that escape disease in the larval and cocooned stages.

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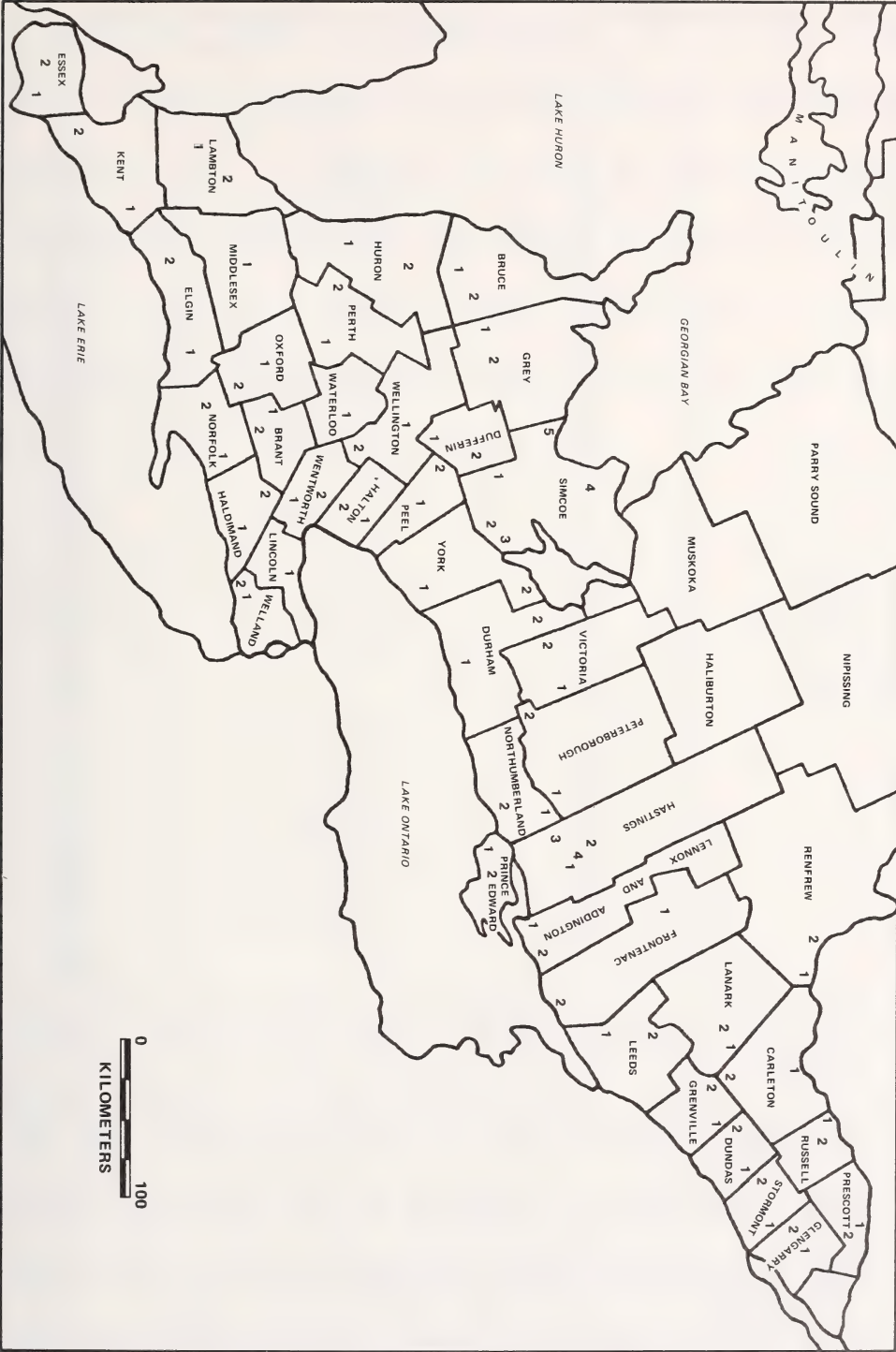


FIGURE 1. Sampling sites for *M. aethiopoulos* in southern Ontario, 1979.

TABLE I. Parasitism of the alfalfa weevil in Ontario by the first generation of *M. aethioides*, 1979.

County	Site	% Parasitism	County	Site	% Parasitism
Brant	1	58.3	Lennox & Addington	1	72.7
	2	12.9		2	91.7
Bruce	1	18.8	Lincoln	1	51.8
	2	37.7	Middlesex	1	59.4
Carleton	1	66.7	Norfolk	1	53.8
	2	68.6		2	80.1
Dufferin	1	90.0	Northumberland	1	43.3
	2	45.4		2	77.8
Dundas	1	33.3		3	72.7
	2	54.5	Oxford	1	80.0
Durham	1	87.0		2	58.1
	2	65.0	Peel	1	31.6
Elgin	1	43.8		2	44.7
	2	44.4	Perth	1	29.4
Essex	1	75.0		2	49.0
	2	50.0	Peterborough	1	60.8
Frontenac	1	50.0		2	70.0
	2	80.0	Prescott	1	63.3
Grey	1	15.7		2	68.0
	2	27.5	Prince Edward	1	80.0
Glengarry	1	60.0		2	86.4
	2	45.1	Renfrew	1	75.0
Grenville	1	72.7		2	59.5
	2	55.0	Russell	1	60.0
Haldimand	1	36.7		2	73.9
	2	50.7	Simcoe	1	69.6
Halton	1	73.7		2	38.0
	2	86.9		3	53.8
Hastings	1	83.8		4	49.8
	2	77.4		5	56.2
	3	78.9	Stormont	1	38.9
	4	91.7		2	44.0
Huron	1	37.8	Victoria	1	73.5
	2	33.3		2	66.6
Kent	1	63.2	Waterloo	1	19.3
	2	40.0	Welland	1	57.5
Lambton	1	71.4		2	66.7
	2	61.5	Wellington	1	69.2
Lanark	1	59.2		2	74.5
	2	62.5	Wentworth	1	83.3
Leeds	1	56.0		2	65.5
	2	56.6	York	1	86.2
				2	81.7

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**THE POTATO LEAFHOPPER,
EMPOASCA FABAE
(HOMOPTERA: CICADELLIDAE)
AND OTHER PESTS OF PEANUTS IN ONTARIO**

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Abstract

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Observations on peanuts in Ontario over a ten-year period showed that the potato leafhopper, *Empoasca fabae* (Harris), was the most consistent and important pest. The cutworms, *Euxoa messoria* (Harris) and *Peridroma saucia* (Hübner), were sometimes present and will occasionally require control. The tobacco thrips, *Frankliniella fusca* (Hinds) was not found and neither thrips nor aphids were important.

Introduction

Research was initiated in Ontario in 1970 to explore peanuts as an alternative crop on the sandy, tobacco lands of the Delhi area of southwestern Ontario. Early results were promising and the program was expanded in 1974 under the New Crop Development Fund of Agriculture Canada. Some pest problems were evident and in preparation for commercial production it became essential to identify insect pests as a first step towards obtaining efficacy data to support the Canadian registration of effective insecticides where necessary. Reported here are observations on pests of Spanish and Valencia peanuts in Ontario over the 10-year period from 1970 to 1979.

Potato leafhopper, Empoasca fabae (Harris)

The most consistent and important pest every year was the potato leafhopper. Adults of this pest disperse into Ontario from the south each year and can be collected from various crops by the first week of June. These migrants colonized the peanuts and significant populations of nymphs were present by early July; 15/plant July 12, 1976, 8/plant July 13, 1977 and 13/plant July 12, 1978. In non-treated peanuts the population often reached 40 nymphs/plant in late July or early August. The numbers of adults swept from non-sprayed Spanish peanuts on three farms in 1978 are shown in Fig. 1. The initial influx of migrant adults was typically followed by declining numbers until the second week of July when recruitment of first generation adults swelled the population to as many as 16 adults/sweep. A second peak began the last week of August as the peanuts were maturing and was not of significance.

Feeding by the potato leafhopper caused chlorosis of the leaves (Fig. 2C) followed by necrosis at the tip and margins of the leaves, a condition known as hopperburn (Fig. 2D), and this contributed to leaflet drop at the base of the plants (Fig. 2F). These symptoms became noticeable every year by July and indicated a pest problem requiring chemical control and, in fact, all the peanuts used in agronomic experiments were routinely protected by planting time treatments with systemic insecticide (carbofuran or aldicarb) and/or by foliar sprays of carbaryl.

The potato leafhopper has been described as an important pest of peanuts in Virginia (Poos *et al.* 1947) and chemical controls are registered for this pest in the U.S.A. The efficacy of various chemical controls and the significance of these populations are discussed elsewhere.

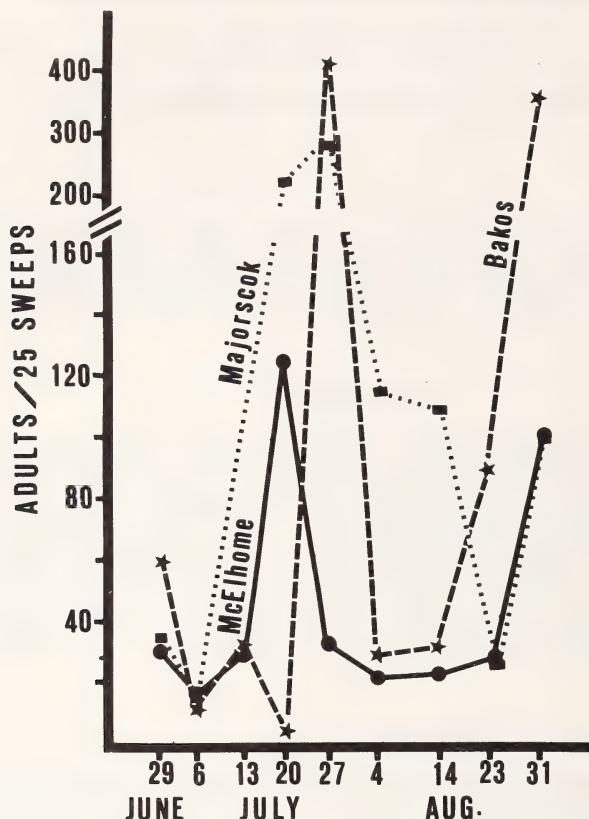


FIGURE 1. The seasonal abundance of adult potato leafhoppers on non-treated peanuts on three farms near Delhi, Ont., 1978.

In addition to chlorosis and hopperburn, an influx of adult leafhoppers was often associated with the presence of single wilted leaves on the tops of the plants (Fig. 2G). These flaccid leaves were more prevalent during times of moisture stress such as dry periods and in the mid-afternoon. That this symptom was related to the presence of adult potato leafhoppers was confirmed in field cages. These cages, 45 x 60 x 82 cm, each enclosed five peanut plants and were infested with from zero to six adult leafhoppers on July 5. Six days later on July 11, all of the cages with six leafhoppers contained "wilted leaves" whereas this symptom was absent in all the controls. The symptom was still appearing in the infested cages after eight days and by that time some of the leaves that were wilted earlier were reduced to a petiole stub without leaflets. A large influx of leafhoppers from July 7 to 13, 1977 resulted in the most noticeable symptoms during the years of this study. There is no evidence that *E. fabae* is a vector of viruses (Nielson 1968), and the cause of the wilting is not known.

A second species of leafhopper became numerous in one area of non-sprayed peanuts near Delhi, Ontario the second week of July, 1978. This species was identified by Dr. K. G. A. Hamilton of the Biosystemics Research Institute, Ottawa as of *Amplicephalus inimica* (Say), the painted leafhopper. In no other instance was this species noticed on peanuts and it probably dispersed from surrounding

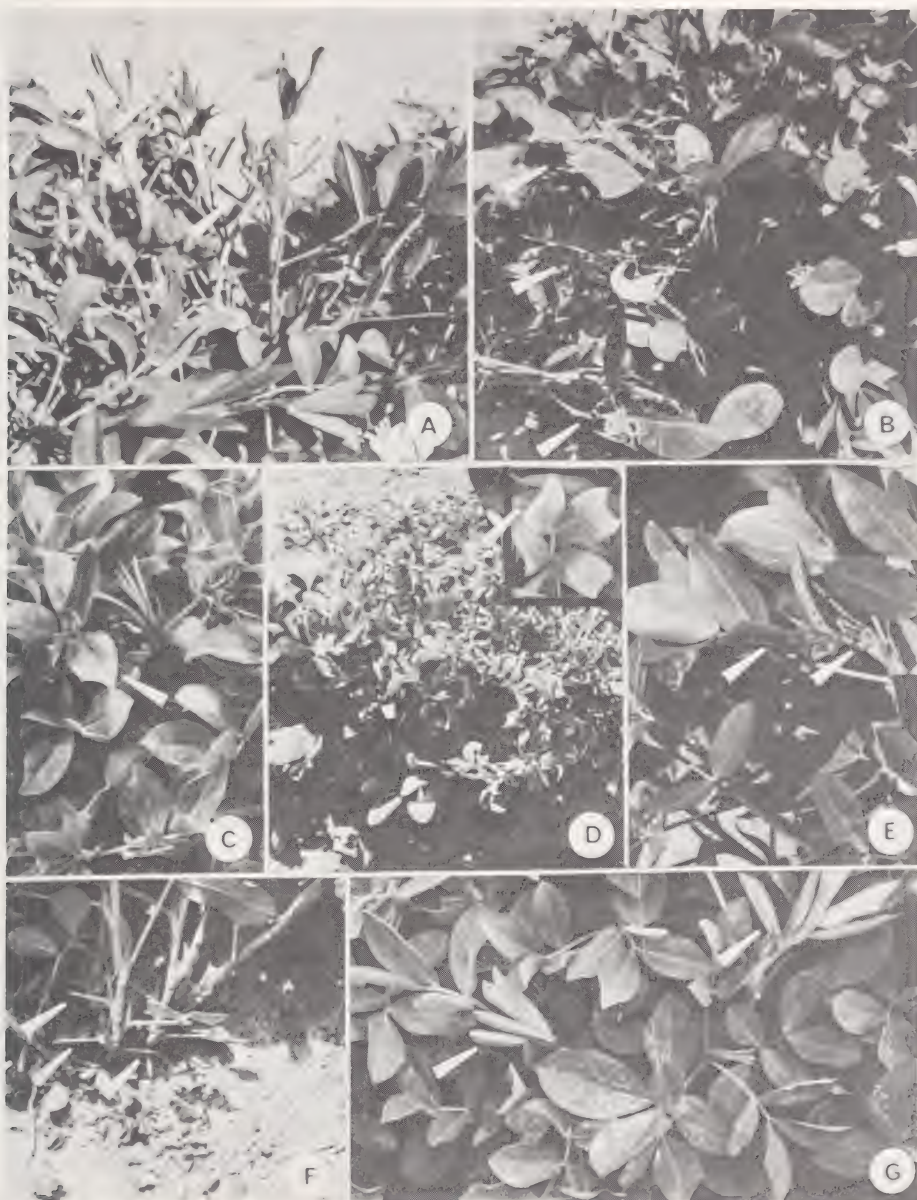


FIGURE 2. Foliar injury to peanuts at Delhi, Ont.; A, leaf removal by groundhogs; B, leaves chewed by cutworms, *Peridroma saucia* (Hübner); C and D, leaf injury by the potato leafhopper, C, chlorosis, and D, tip necrosis; E, cowpea aphids; F, basal leaf drop; G, wilted leaves associated with presence of potato leafhoppers.

fields of weeds. *Macrosteles fascifrons* (Stål), the aster leafhopper, was collected as adults at densities of less than one per sweep from most unsprayed peanut fields in June and early July but also is not considered a pest of peanuts.

Cutworms

The dark-sided cutworm, *Euxoa messoria* (Harris), attacks a number of crops in southwestern Ontario and is a serious pest of tobacco (Cheng 1971, 73). This species occasionally injured peanuts by pruning leaves but some cutworms could be supported on peanuts without plant mortality. Rye is the preferred host for oviposition in the fall and the first three instars feed on the rye until it is plowed under or broken down (Cheng 1971). Problems are most likely to be located where dark-sided cutworms have dispersed from rye into adjacent peanuts or possibly where a rye rotation crop has been plowed under.

Some field cages that covered unsprayed peanuts in 1977 were naturally infested with cutworms. Five of the 48 cages contained cutworms and damage was noticeable by July 11 (Fig. 2B). Some of the larvae were reared to adults and the identification confirmed by Dr. E. W. Rockburne of BRI, Ottawa, as the variegated cutworm, *Peridroma saucia* (Hübner). This species is common in southwestern Ontario and periodically damages vegetable and field crops in the early season and is of most concern in mid-summer (Harris *et al.* 1977).

Thrips

The tobacco thrips, *Frankliniella fusca* (Hinds), causes its main visible injury to the developing leaflets and flower buds (Poos 1945). Although the effects of this injury on yield have been inconsistent (Smith 1972), insecticides are recommended in the USA for thrips control and there has been a program to develop host resistance. The tobacco thrips is present in Ontario but of minor interest and no controls are recommended for thrips on Ontario tobacco (Ontario Ministry of Agriculture and Food 1979). Plants with crinkled leaves and suspected of having thrips were examined during the period 1976-78. Thrips were rare and those few specimens collected from peanuts were identified by Dr. B. S. Heming of the University of Alberta as *F. tritici* (Fitch), the flower thrips. This species is common on many plants but is not a pest of peanuts. Thrips should not be a problem on peanuts in Ontario.

Aphids

Although various alate aphids were found on peanuts in Ontario, in only one instance did colonization occur (Fig. 2E). Unfortunately the specimens were lost before identification could be confirmed. The species was most likely the cowpea aphid, *Aphis craccivora* Koch., a pest of peanuts in the USA and, although not reported from Ontario, present in Quebec and New York, areas that are contiguous with Ontario (Smith and Parron 1978). No problems are anticipated with aphids on Ontario peanuts.

Groundhogs

In checking for injury by leaf-feeding insects, the most common injury seen was that caused by groundhogs (Fig. 1A). The sandy soils being investigated for peanut production dried out quickly and the lush green peanut growth was an attractive food for groundhogs with burrows in banks and bush along field mar-

gins. The leaf removal on the tops of the plants (Fig. 1A) was easily distinguished from the leaf drop at the base of the plants associated with leafhoppers or other stress (Fig. 1F).

Acknowledgments

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TWO NEW SPECIES OF *ELAMPUS*
(HYMENOPTERA: CHRYSIDIDAE) FROM PUERTO RICO
AND CUBA WITH NOTES ON *ELAMPUS VIRIDIS* CRESSON

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Abstract *Proc. ent. Soc. Ont.* 110: 47-51 (1979)

Two new species, *Elampus puertoricensis* Huber from Puerto Rico and *E. cubanus* Huber from Cuba, are described. The relationship of these species to other western hemisphere *Elampus* is discussed. *E. rotundus* Huber and Pengelly is newly synonymized with *E. viridis* Cresson. A key to species is presented.

Introduction

Only one species of *Elampus*, *E. viridis* Cresson from Cuba (Cresson 1865), has been described from the Caribbean region. Two new species are described herein, one from Puerto Rico and one from Cuba. The Puerto Rican species represents the first record of the family Chrysididae from the island (Wolcott 1936, 1941).

Most of the terminology used in this paper is the same as described in a revision of the North American *Elampus* (Huber and Pengelly 1977).

Key to Cuban and Puerto Rican species of *Elampus*

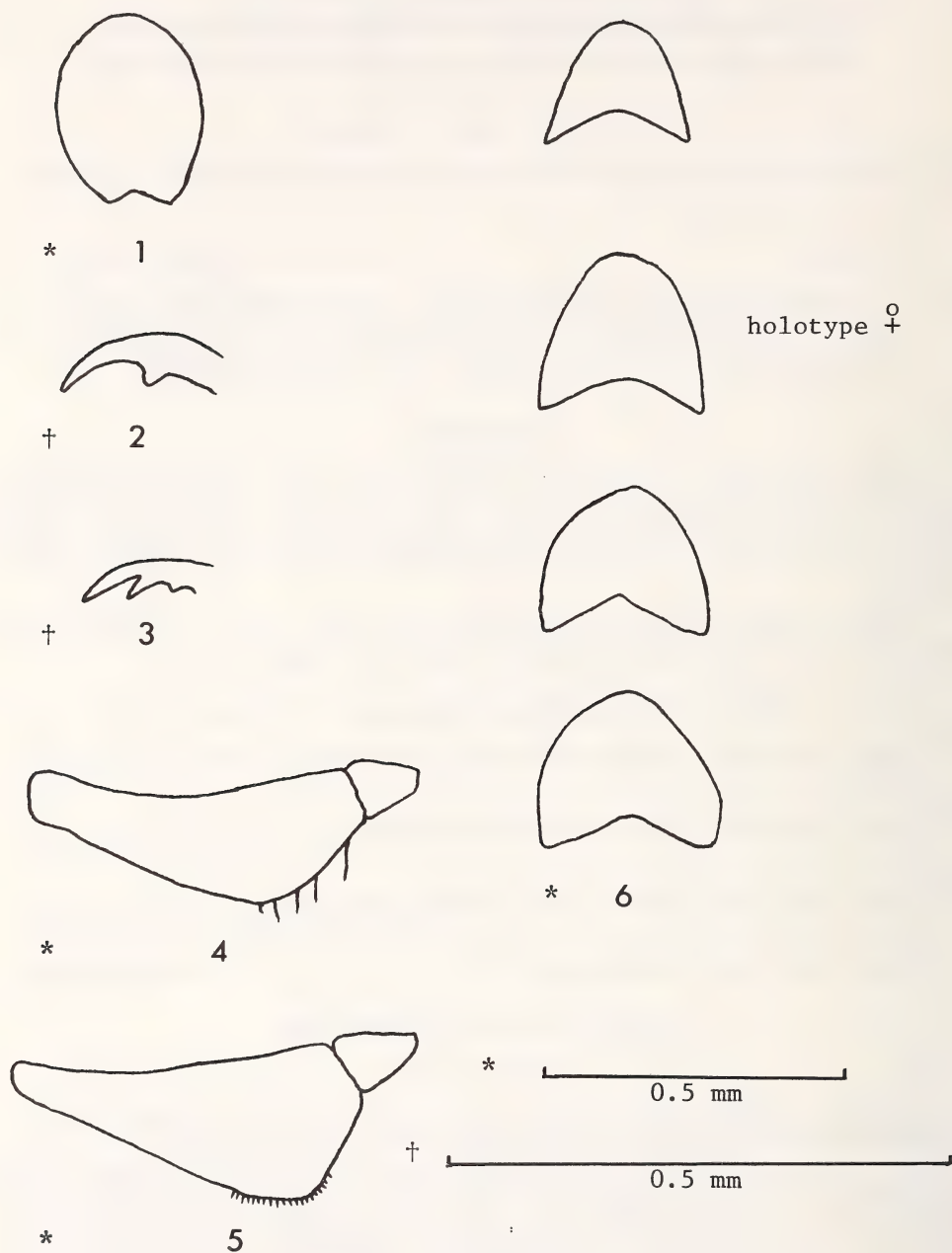
- 1. Apical truncation of third tergite circular or oval with a small ventral notch (Fig. 1) 2
- Apical truncation of third tergite crescent shaped (Fig. 6) *cubanus* Huber n. sp.
- 2. Head, thorax, and abdomen with extensive copper, gold, or red..... *puertoricensis* Huber n. sp.
- Head, thorax, and abdomen green *viridis* Cresson

Elampus puertoricensis Huber n. sp.

(Figs. 1, 2, 4)

Holotype female. “Puerto Rico, Lajas, Sept.-Nov. 1960, M. Beauchamp.” (United States National Museum, Washington, D.C. Type no. 73819). Female (holotype). Length 5.4 mm. Bright green with gold and/or copper tinge or reflections on the following: scape, vertex especially in front of anterior ocellus, genae above, pronotum medially, in punctures of mesopleura and scutellum, in basal and lateral punctures of postscutellum, underside of postscutellar blade, propodeum, legs except for tarsi and apex of tibiae, posterior part of first and second tergites, third tergite except apically and along lateral margins. The copper colour is most pronounced laterally on the second tergite. Mesothorax red becom-

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FIGURES 1-6. 1, 2, 4, *Elampus puertoricensis* Huber n. sp., female. 1, face view of apical truncation of abdomen; 2, tarsal claw; 4, lateral view of fore femur. 3, 5, 6, *Elampus cubanus* Huber, n. sp., female. 3, tarsal claw; 5, lateral view of fore femur; 6, face view of apical truncation of abdomen showing variations.

ing gold anteriorly between notaulices. Rims of punctures on scutellum, apex of postscutellar blade, and junction of propodeum and first tergite black. Flagellum and pedicel dark brown. Apex of tibiae and tarsi brownish-yellow. Fore wing clear basally, lightly brown-stained beyond venation. Sternites with a narrow, coppery-purple, longitudinal line medially. Lateral margins and apex of third tergite pink. Apical truncation of third tergite light brown above, dark brown below, with a dark brown rim.

Scapal basin smooth above, roughened to rugose below and laterally. Genal fringe somewhat setose, setae one ocellar-diameter in length and irregularly spaced. Pronotal punctures medium in size, densely spaced to contiguous medially. Base of fore femora below barely angular (Fig. 4). Tarsal claws with one small, vertical inner tooth (Fig. 2). First tergite smooth above basal pit with a few small, scattered punctures lateral to it and mostly minute, densely to moderately spaced punctures along posterior margin. Second tergite with a narrow, indistinct, longitudinal smooth line medially extending about half the length of the tergite. Apical truncation of third tergite oval with a very shallow ventral notch (Fig. 1).

Measurements (in mm) and ratios as follows: width/length of head 2.4; width/length of pronotum 1.7; width/length of tergites II and III 1.6, 1.6 respectively; width/height of apical truncation 0.50; length of flagellomeres I/II 1.7; fore wing length 3.6; stigmal length 0.33; radial sector length 0.18; distance between compound eyes 0.91; distance from median ocellus to clypeal margin 0.97; length of scape 0.44; POL 0.29; OOL 0.26.

Male. Unknown.

Biology. Unknown.

Remarks. The combination of the smooth, coppery-gold scapal basin, red and gold mesothorax, oval apical truncation with a very shallow ventral notch, and the single vertical, inner tooth in each tarsal claw separates *E. puertoricensis* from other *Elampus*.

E. puertoricensis is most closely related to *E. viridis* Cresson from North America and Cuba on the basis of the very short radial sector and the single, vertical tooth in the tarsal claw. Together with *E. gayi* Spinola from South America, these three species have in common a circular or oval apical truncation of the third tergite. The rather long, sparse genal fringe is unusual in that it is a male character, the females having a short, dense, setose fringe, at least in the North American *Elampus*.

Elampus cubanus Huber n. sp.

(Figs. 3, 5, 6)

Holotype female. [Cuba] "Guane P. Rio, P. Alayo IX-1967. "(Biosystematics Research Institute, Ottawa).

Female (holotype). Length 4.8 mm. Green with occasional violet or blue tinge or reflections on the following: scape, scapal basin, genae, pro- and mesonotum, mesopleura. Flagellum and pedicel brown. Apex of tibiae and tarsi yellowish-brown. Fore wings tinged with brown beyond venation. Apical truncation of third tergite brown. Rims of punctures of scutellum, postscutellum, and apex of postscutellar blade black.

Scapal basin rugose. Genal fringe short, dense, setose. Punctures on dorsum of pronotum moderately spaced medially. Base of fore femora below rounded with

a short, dense, setose fringe (Fig. 5). Tarsal claws with two inner teeth (Fig. 3). First tergite with minute, scattered punctures around basal pit, sparsely spaced on remainder of tergite. Second tergite with minute, densely spaced punctures. Apical truncation of third tergite crescent shaped, ventral notch less than half the height of truncation (Fig. 6).

Measurements (in mm) and ratios as follows: width/length of head 2.4; width/length of pronotum 1.9; width/length of tergites II and III 1.3, 1.2 respectively; width/height of apical truncation 1.1; length of flagellomere I/II 1.6; fore wing length 3.3; stigma length 0.26; radial sector length 0.18; distance between compound eyes 0.82; distance from median ocellus to clypeal margin 0.88; length of scape 0.38; POL 0.28; OOL 0.26.

Male. Unknown.

Biology. Unknown.

Paratypes: CUBA: Guane (1 ♀); Santiago de las Vegas, Habana (1 ♀) (University of Guelph, Guelph).

Other material examined. Baracoa (1 ♀) (United States National Museum); Guane P. Rio, IX-1967 (1 ♀) (P. Alayo) (University of California, Davis).

Remarks. The length of three specimens (2 paratypes and specimen from Baracoa) ranged from 3.8-4.3 mm. The colour of the apical truncation of the third tergite varied from yellow to brown, and the shape varied as shown in Fig. 6. Punctuation on the first tergite varied from smooth to moderate, and on the pronotum from moderate to sparse.

The combination of the rugose scapal basin and two inner teeth in each claw relates this species to *E. hyalinus* (Aaron) from North America. It differs from the latter by the brownish fore wings.

Alayo (1974) recorded *E. viridis* from Guane P. Rio and Santiago de las Vegas, Habana. These two records should be referred to *E. cubanus* n. sp. Possibly his other locality records should be referred to *E. cubanus* as well.

Elampus viridis Cresson

Elampus viridis Cresson, 1865. *Proc. ent. Soc. Phil.* **4**: 103. Original description.

Elampus viridis: Norton, 1879. *Trans. Am. ent. Soc.* **7**: 235. Redescription.

Elampus viridis: Provancher, 1881. *Nat. Canad.* **12**: 303. Redescription. (?) Canadian record.

Elampus viridis: Aaron, 1885. *Trans. Am. ent. Soc.* **12**: 219. Synonymy under *Notozus marginatus* Patton.

Ellampus viridis: Mocsary, 1889. *Monogr. Chrysididarum*. p. 78. Descriptions quoted.

Ellampus viridis: Dalla Torre, 1892. *Catalogus Hymenopterorum* **4**: 20. World catalogue.

Notozus viridis: Bischoff, 1913. *Gen. Insectorum* **151**: 7. World catalogue.

Elampus viridis: Cresson, 1928. *Mem. Am. ent. Soc.* **5**: 30. Type material.

Elampus viridis: Bodenstein, 1951. *U.S. Dep. Agric., Agric. Monogr.* **2**: 719. Synonymy under *E. marginatus* (Patton).

Elampus viridis: Alayo, 1974. *Acad. Cien. Cuba. Serie Biol.* **52**: 12. Cuban records (= *E. cubanus* n. sp.).

Elampus rotundus Huber & Pengelly, 1977. *Proc. ent. Soc. Ont.* **108**: 92 NEW SYNONYMY.

Remarks. The holotype of *E. viridis* was examined in the Academy of Natural Sciences, Philadelphia. It is glued to a card and is in very poor condition with the head, pronotum, left wings, and part or all of four legs missing. The right fore wing and two complete legs are glued separately to the card. There is a pin hole through the mesothorax. Despite its condition three important characters *viz.*, the apical truncation of the third tergite, tarsal claws, and radial sector are visible and permit the synonymy of *E. rotundus* Huber and Pengelly with *E. viridis* to be made. The holotype is labelled as follows: "Cuba" (white label), "Type No. 2682" (red label), "3 teeth in claw" (pink handwritten label), "*Elampus viridis* (Type) Cresson. The specimen was almost destroyed in some way and was at first pinned" (pink handwritten label). There is, in fact, only a single tooth in each tarsal claw. A complete description and distribution in North America of this species is given (as *E. rotundus*) by Huber and Pengelly (1977). Since then, six specimens of *E. viridis* labelled "Havana, Cuba, Baker" were seen in the University of California, Davis. The Provancher record of *E. viridis* occurring in Canada needs confirmation as his collection in Quebec City does not contain any specimens referable to this species.

Acknowledgments

Sincere thanks are extended to the following people who allowed material of *Elampus* to be examined in their institutions or who provided material for study: Dr. K. V. Krombein, United States National Museum, Washington, D.C., Mrs. P. Francis, Academy of Natural Sciences, Philadelphia, and Dr. L. Kimsey, Department of Entomology, University of California, Davis. Dr. P. Alayo D., Academia de Ciencias de Cuba, Instituto de Zoologica, Havana, kindly donated specimens of *E. cubanus* to the University of Guelph. This work was supported, in part, by the Canada Department of Agriculture Grant 4033.

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(Received 28 April 1980)

TEMPERATURE RELATIONSHIPS TO FORECAST HATCHING OF OVERWINTERED EGGS OF THE EUROPEAN RED MITE, *PANONYCHUS ULMI* (ACARINA: TETRANYCHIDAE)

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Abstract

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The influence of temperature and humidity, and the importance of available moisture expressed as vapour pressure deficit on the development of overwintered eggs of European red mite, *Panonychus ulmi* (Koch), is described. The threshold for egg development was determined as *ca.* 5.6°C. Degree-day (*dd*) summations determined in the laboratory were field tested for their precision in predicting first and 50% hatch. Summation of 155 *dd* above 5.6°C after March 1 can be used to predict first hatch in the field, accurate to within one day; *dd* summations to 50% hatch were more variable but based on 250 *dd* after March 1, predicted and observed dates of 50% hatch were within three days. Biometeorological indices, based on *dd* summations above the temperature threshold 5.6°C, should prove useful in Integrated Pest Management programmes to forecast hatching time of overwintered *P. ulmi* eggs in widely different climatic areas.

Introduction

The European red mite, *Panonychus ulmi* (Koch), (ERM) is one of the major pests in peach and apple orchards. In southern Ontario *P. ulmi* has six to eight generations a year and must be controlled by acaricide treatments when mite numbers reach critical levels. In recent years, effort to reduce pesticide use in orchard ecosystems has directed our studies at Vineland Station toward development of biometeorological indices to optimize timing of pesticide applications for *Laspeyresia pomonella* (L.), *Rhagoletis pomonella* (Walsh) (Trottier, in press) and *Phyllonorycter blancardella* (Fab.) (Johnson, Trottier and Laing 1978). While the trend, in orchards under pest management, is to apply sprays only when ERM numbers reach critical levels, it is important to determine accurately the time of hatching of ERM overwintered eggs so that predictive models (Herne and Lund 1979) can be effective in predicting ERM critical levels during the summer. In Ontario, Herne and Trottier (1975) showed that the dates of first hatch of the ERM overwintered eggs varied greatly among the major apple growing areas, and the number of days between first hatch and full bloom (cv. McIntosh) ranged from 5 to 14 days. Wide variation was also observed in the relationship between fruit bud development and first hatch of the overwintered eggs. In peach orchards, overwintered eggs hatched usually within a 2-week period but in some years this took three weeks. Consequently a more accurate method, applicable to peach and apple orchards, was required to forecast hatching of overwintered eggs of the European red mite.

Predicting the beginning of hatch, or 50% hatch, on the basis of accumulated degree-days has been unsuccessful in England (Light *et al.* 1968). Extended hatching periods, variation from year to year in the date of peak hatch, and variation of peak hatch from one orchard to another are factors that rendered

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forecasting difficult. Cranham (1972) showed however, that a close forecast of the date of 50% hatch in England depended on two factors, effectiveness of chilling and accumulated degree-days. In Japan, Tsugawa *et al.* (1961) have been successful in forecasting first hatch of ERM overwintered eggs from temperatures in March and April. However, hatching there was more synchronized than in Ontario; 99% of the hatch in the field occurred within ten days, mainly before the blossom period.

This paper reports on the influence of temperature, humidity, and vapour pressure deficit (V.P.D.) on the development of ERM overwintered eggs and describes methods of degree-day summations to forecast first and 50% hatch, and the subsequent testing of the indices under Ontario conditions.

Materials and Methods

Twigs infested with ERM overwintered eggs were collected in March from a sour cherry orchard near Vineland, Ontario. Twigs of *ca.* 1.5-cm diameter were cut in the orchard into 10-cm lengths. In an open-sided insectary, twigs were examined under a binocular microscope and a twig section bearing about 100 viable eggs was selected and ringed with polybutene stickem. Twigs were secured to wire mesh platforms with florists' clay. Twigs and platforms were then placed in clear plastic containers (17 x 12 x 6 cm) and moved to the laboratory. In the laboratory, 100 ml of specific saturated salt solutions were poured into the bottoms of the containers to maintain the constant relative humidity (Winston and Bates 1960) and achieve a desired V.P.D. Containers were closed with clear plastic covers and moved into appropriate constant temperature cabinets with a 16L:8D photoperiod regime. Relative humidities were maintained within $\pm 5\%$ as follows: 10.0°C, 40 and 70%; 12.5°C, 70% R.H.; 15.0°C, 55, 70, and 80% R.H.; 17.5°C, 70% R.H.; 20.0°C, 70 and 85% R.H.

Each of the nine treatments was replicated three times. Hatching was monitored by examining the eggs daily in a 5°C room with a binocular microscope and emerged larvae caught in the stickem were removed with a needle. Data were subjected to Duncan's multiple range test. Multiple stepwise regression analyses were also conducted to determine the influence of temperature and humidity on development of ERM overwintered eggs. The temperature threshold of development was estimated by subjecting data for days to first and 50% hatch relative to constant laboratory conditions of 10 to 20°C, in increments of 2.5°C, and 70% R.H. to two types of mathematical treatments. One treatment consisted of solving the linear function: $Y = a + bx$, where Y was the rate of development at temperature X , and a and b were constants; the intercept and slope respectively. The second treatment consisted of solving the hyperbolic function (Trottier 1971): $T = a_1/(X - Th)$, where T was the time for first or 50% hatch at temperature X ; Th was the calculated temperature threshold, and a_1 was the minimal accumulated temperature in degree-days above Th .

The temperature threshold established from laboratory data that offered the least variation in degree days among the temperature treatments was used to calculate degree-days to first and 50% hatch in the field.

Two methods of *dd* summation were evaluated for estimating ERM egg development in the field. They were:

$$1) \text{ } dd = dd_1 = (T \text{ max} + T \text{ min})/2 - Th$$

$$2) \text{ } dd = dd_2 = \begin{cases} (T \text{ max} + T \text{ min})/2 - Th & \text{for } T \text{ min} \geq Th \\ (T \text{ max} + Th)/2 - Th & \text{for } T \text{ min} < Th \end{cases}$$

where T_{max} and T_{min} are respectively the maximum and minimum temperatures for the day, and T_h is the temperature threshold established in the laboratory.

Maximum and minimum temperatures were recorded with an accuracy of $\pm 0.5^{\circ}\text{C}$ in standard Stevenson Screens located in the orchards. Degree-days (dd) were accumulated daily from March 1 and April 1 to the day of occurrence of first and 50% hatch in the field.

Degree-day relationships to first hatch in the field were tested by using the 1969-73 data from peach orchards in the Jordan-Vineland area (Herne and Trotter 1975). Degree-day relationships to first and 50% hatch were also tested by using biological and weather data from apple orchards in different climatic areas over the years 1971-1978.

Results and Discussion

Laboratory study

At all temperatures the rate of egg development to first hatch was about 1.5 times faster than to 50% hatch (Table 1). The interval between first hatch and

TABLE I. Days for hatching of diapause eggs of *P. ulmi* and percentage of eggs hatching at different constant temperatures and 70% relative humidity.

Temp °C	Number Eggs	Mean % Hatch	No. Days for Hatching		
			First	50%	100%
10.0	310	43.5 a	38 (2.63)*	56.0 (1.79)*	90 (1.1)*
12.5	296	77.4 b	28 (3.57)	43.5 (2.30)	83 (1.2)
15.0	298	56.4 c	20 (5.00)	32.5 (2.08)	58 (1.72)
17.5	297	39.1 d	15 (6.67)	23.5 (4.26)	49 (2.09)
20.0	306	56.5 c	10 (10.00)	16.5 (6.06)	34 (2.94)

Means followed by different letter are significantly different from each other at the 0.05 probability level.

* Percentage development per day in ().

50% hatch increases as temperature decreases. Per cent hatch at 12.5°C was larger ($P < 0.05$) than at the other temperatures, while at 17.5°C per cent hatch was smaller ($P < 0.05$). Cranham (1972) found that the per cent hatch was greater at 15 than at 21°C. The linear and hyperbolic functions in this study were solved by using the interval to hatch data (Table II). The temperature threshold for development, $5.6 \pm 0.5^{\circ}\text{C}$, gave the least variance between temperature treatments; the coefficient of variability (C.V.) ranged from 11.3 to 15.3% for estimating mean dd to first hatch; from the interval to 50% hatch, the temperature threshold of $5.1 \pm 0.5^{\circ}\text{C}$ allowed the best estimates (C.V. ranged from 11.5 to

TABLE II. Temperature threshold (T_h) and mean degree-days (dd), for development of overwintered eggs of *P. ulmi* incubated at constant temperature and 70% relative humidity, estimated by two methods.

Function	First Hatch		50% Hatch	
	T_h (°C)	$dd \pm (\text{S.D.})^*$	T_h (°C)	$dd \pm (\text{S.D.})$
$Y = a + bX$	7.2	$138.7 \pm (21.2)$	6.7	$236.0 \pm (34.0)$
$T = a_i/(X - T_h)$	5.6	$174.2 \pm (19.6)$	5.1	$291.9 \pm (33.5)$

* Standard deviation

14.4%). Table II shows that the temperature threshold 5.6°C, which produced the least variance is the best estimator for ERM overwintered egg development. Therefore *dd* to first hatch and 50% hatch in the field are predicted to approximate 175 and 275 respectively. Cranham (1972) calculated the threshold of winter eggs of *P. ulmi* by fitting a linear regression between rate of development and temperature, but warned of the limitation of extrapolation methods. Although he calculated that the threshold was within the range 5.5-7°C, the lowest temperature permitting development and eclosion of a high proportion of winter eggs was 9°C; for a small percentage it was 8°C.

Lees (1953) stated the threshold for post-diapause development of *P. ulmi* winter eggs was 7°C, although he did not indicate whether eclosion would occur. Parent (1965) used an extrapolation method and found the threshold of summer eggs to be 8.9°C. Mori (1957) also determined by extrapolation that the development threshold of summer eggs was 9.03°C but stated the real threshold was probably lower because the extrapolated line was merely theoretical and 'practically' the line was s-shaped with the ends curved. Putman (1970) working with summer eggs, determined the lowest experimental temperature at which eggs completed embryonic development and hatched was 10.8°C., but considered the threshold to be 1 to 3°C lower.

At 10°C, but not at 15°C, V.P.D. influenced days to first and 50% hatch (Table III); days before hatching increased with low humidity. This may be due to the lower hatch recorded at low humidity ($P < 0.05$). No significant influence,

TABLE III. Effect of temperature and vapour pressure deficit (V.P.D.) on hatching of overwintered eggs of *P. ulmi* under constant laboratory conditions.

Temp. (°C)	V.P.D. (mb)	R.H. (%)	Number Eggs	Mean % Hatch	No. Days for Hatching		
					First	50%	100%
10	3.68	70	310	43.5 a	38 a	56.0 a	90 a
15	3.41	80	298	49.0 a	19 b	32.0 b	63 b
10	7.36	40	267	13.7 b	46 c	66.7 c	86 a
15	7.67	55	298	25.8 b	21 b	35.5 b	60 b

Means followed by different letter are significantly different from each other at the 0.05 probability level.

however, was found in our study for days to total hatch. Table I shows that optimum hatch occurred at 12.5°C and 70% R.H. or at a V.P.D. of 4.346 mb. Any departure below or above these conditions reduce per cent hatch (Table III).

Table IV shows the combined effect of temperature and V.P.D. on rate of development of ERM overwintered eggs. Temperature alone explains about 94% of the variance between treatments, and V.P.D. 97%. However, 99% of the variance is explained by the multiple regression models,

$$Y_1 = -0.0663 - 0.0134 X + 0.0616 X_1$$

$$Y_2 = -0.0369 - 0.0079 X + 0.0364 X_1$$

where Y_1 is the rate of development to first hatch, Y_2 is the rate of development to 50% hatch, X is temperature, and X_1 is V.P.D. Therefore, temperature and available moisture have a synergistic effect on rate of development. Furthermore, it is clear from Table IV, although relative humidity was constant (70%), that V.P.D. increased from 3.682 mb at 10°C to 7.012 mb at 20°C. Tables I, III and IV show

therefore, that available moisture expressed as V.P.D. has a significant influence on ERM egg development and that relative humidity is a less useful expression of ambient moisture conditions.

Mori (1957) showed with summer eggs of *P. ulmi* the importance of the amount of water vapour present in a given volume of air on embryonic development and hatching. For example at 17% R.H. the per cent of embryos developing (but not hatching) was 0 and 48% at temperatures of 15 and 20°C respectively.

TABLE IV. Effect of temperature (X) and vapour pressure deficit (V.P.D.) (X_1) on rate of development (Y) of overwintered eggs of *P. ulmi* incubated at constant temperature and 70% relative humidity.

Temp. (°C) (X)	V.P.D. (mb) (X_1)	Rate of development*	
		First Hatch (Y_1)	50% Hatch (Y_2)
10.0	3.682	0.0263	0.0179
12.5	4.346	0.0357	0.0230
15.0	5.113	0.0500	0.0308
17.5	5.997	0.0667	0.0426
20.0	7.012	0.1000	0.0606
Y-Intercept	(a)	—0.0663	—0.0369
Reg. Coeff. 1	(b_1)	—0.0134**	—0.0079***
Reg. Coeff. 2	(b_2)	+0.0616**	+0.0364***
R-Squared	(R^2)	0.9959	0.9994

* Rate of development; $Y = a + b_1X + b_2X_1$

** Significant at the 0.01 probability level. (0.1 < S.L. < 0.05)

*** Significant at the 0.05 probability level. (0.05 < S.L. < 0.01)

At 28-33% R.H. the per cent hatch was 0 and 13% at temperatures of 15 and 20°C respectively. A given volume of air with the same relative humidity obviously holds more water vapour at 20 than at 15°C.

Field Study

In Table V the lowest C.V. occurs with dd_2 summations indicating that this is the more accurate way to calculate dd above 5.6°C to first hatch in peach orchards, and that summations should start from 1 March near Vineland, Ontario. For other fruit growing areas summations of dd_2 should start when maximum

TABLE V. Comparison of degree-day (dd) summations above 5.6°C (Th) to forecast first hatch of overwintered eggs of *P. ulmi* in a peach orchard.

	Date of First Hatch	Degree-day Summations			
		Including March °C		Excluding March °C	
		dd_1	dd_2	dd_1	dd_2
Mean	7 May	112	157	105	137
Coefficient of Variation (%)	19	15	8	20	19

temperatures exceed 5.6°C. The C.V. was 8% for dd_2 summations starting in March compared to 15, 19 and 20% for the other methods. Therefore *ca* 155 dd_2 above 5.6°C after March 1 can be used to predict first hatch in the field. However, this value is 20 dd_2 lower than the 175 dd established in the laboratory. Such

TABLE VI. Predicted (P)* and observed (O) dates of first hatch and 50 % hatch of overwintered eggs of *P. ulmi* in Ontario apple growing areas.

Area	1st Hatch						50% Hatch					
	Year			Year			Year			Year		
	1972		1973		1974		1971		1972		1972	
Simcoe	(P)	(O)	(P)	(O)	(P)	(O)	(P)	(O)	(P)	(O)	(P)	(O)
Vineland	14 May	13	24 Apr	23	1 May	1	24 May	24	22 May	19	22 May	19
Trenton	16 May	15	2 May	2	30 Apr	30	21 May	24	26 May	25	26 May	25
	17 May	16	30 Apr	30	10 May	11	27 May	27	27 May	28	27 May	28

* 1st hatch and 50% hatch based on 155 *dd.* and 255 *dd.* respectively above 5.6°C from March 1.

a difference may be related to the influence of V.P.D. on rate of development (Table IV) which was not measured in the field. Based on 155 dd_2 above 5.6°C the predicted dates of ERM first hatch for apple orchards in different climatic growing areas were found to be accurate within one day (Table VI). Since 1975, predicted dates for first hatch of the ERM overwintered eggs, for all major fruit-growing areas, have been used by the extension horticulturists of Ontario as early warnings for the onset of ERM development.

In the laboratory study, dd summations to 50% hatch were found more variable than to first hatch (Table II). For two consecutive years observations were made in three apple growing areas in an effort to relate 50% hatch to dd above 5.6°C after March 1. A sum of 250 $dd_2 \pm 20$ (S.D.) was found to be related to 50% hatch. This value is *ca* 25 dd_2 lower than the 275 dd established in the laboratory. This difference may also be due to the influence of V.P.D. (Table IV). Based on 250 dd_2 , predicted and observed dates of 50% hatch were found to be within three days (Table VII).

This study shows the value of biometeorological indices determined in the laboratory, in predicting biological events. However, such indices often must be modified after field testing to obtain acceptable accuracy for a specific field situation. The dd_2 summations above the temperature threshold (5.6°C), permit accurate forecasting of hatching time of the ERM overwintered eggs in widely different climatic areas. Such information is important and useful in the efficient operation of Integrated Pest Management programmes.

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**INFESTATION OF
MACROSIPHUM AVENAE AND RHOPALOSIPHUM PADI
(HOMOPTERA: APHIDIDAE) ON WINTER WHEAT
IN ESSEX COUNTY, ONTARIO**

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Abstract

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A widespread infestation of aphids on winter wheat was of great concern to growers in Essex County in June, 1979. It was found that light to severe infestations on the heads of wheat at the time that kernels were half-filled did not reduce the yield or test weight of the crop. A heavy driving rain was effective in reducing aphid populations on the plants. Small plots sprayed with malathion demonstrated that effective control was available if necessary.

Introduction

Winter wheat growers in Essex County, Ontario were greatly concerned during June, 1979 because of aphid infestations in their fields. The aphids infested all visible parts of the plants, but of particular concern was the large numbers on the heads at a critical period of grain development. The kernels in many of the fields were only half-filled. A quick decision was necessary as to whether an aerial application of aphicide should be recommended.

The growers said that they had never experienced similar infestations, and the literature failed to provide any useable information on previous infestations, damage, or control studies on winter wheat in Ontario. Because of this lack of available information, our findings are published as a guide for future investigators.

Materials and Methods

Fields were examined in several areas of the county to determine the extent of the infestation, the species of aphids involved, and predator and parasite activity. Sample heads were placed in 70% alcohol and the aphids counted and identified later.

On June 19, a 240 m² area in a field of the Fredrick variety of wheat at Harrow was divided in six equal parts and 150 plants/plot were examined to determine the percentage infestation. Three of these plots were treated with malathion 50 EC at a rate of 1.5 l/ha using a knapsack sprayer. After 24 and 48 hours all plots were examined to assess changes in infestations.

Kernels were removed from infested and uninfested heads on June 20 and examined in the laboratory to observe any injurious effects of the aphids. A 6.75 m² area in each plot was harvested on July 30 to determine yields and test weights (kg/hl).

Results and Discussion

From our observations and those of about 70 growers who either attended meetings or contacted us, it was apparent that the infestation was widespread. Two

species of aphids, namely, the English grain aphid, *Macrosiphum avenae* (Fabricius), and *Rhopalosiphum padi* (L.), sometimes referred to as the oat bird-cherry aphid, were present on most plants examined. The numbers of aphids per plant and the ratio of *M. avenae* to *R. padi* varied so greatly between plants and between fields that a determination of averages per field was meaningless. However, in two samples where counts were made in commercial fields there were 87 and 67/head. In general terms, it could be stated that the infestations ranged from light to severe, with most being in the moderate category. Each field that we observed had coccinellid and syrphid predators and some aphids had been parasitized.

The percentages of plants with infested heads in the six experimental plots before treatment on June 19 were similar (Table I). On June 20, there was a large decrease in the numbers of infested plants in the treated plots, but a small increase

TABLE I. Percentages of winter wheat plants infested with aphids before and after treatment with malathion.

Date	Mean % of plants with infested heads	
	Untreated plots ^a	Treated plots ^a
June 19 ^b	78.7 ± 0.8 ^d	77.8 ± 7.6
June 20 ^c	85.7 ± 1.8	5.3 ± 1.2
June 21	78.7 ± 1.5	6.3 ± 2.4

^a Means based on 3 plots, 150 plants examined per plot.

^b Treatments applied after counts made this date.

^c Heavy rain occurred after counts made this date.

^d Standard error.

in the untreated plots. Despite their small size, large numbers of dead aphids were readily observed on the ground in treated plots. The few treated plants that remained infested usually had only 1 to 3 aphids/head.

The experimental plots and much of the county were affected by a storm soon after the records were taken on June 20. Approximately 24 mm of rain fell on the plots within a few hours and there was a moderately strong wind. Examination on June 21 showed that this driving rain resulted in a substantial decrease in the number of aphids per head in untreated plots, although there was only a slight decrease in the percentage of infested plants (Table I). Large decreases were also observed in a commercial field where the average number per head was 78 before the storm and 15 after. Limited data from a commercial field showed that 74% of the adult aphids on the heads were *R. padi* on June 19 but only 4% were of this species on June 21, so this smaller species appeared to have suffered more from the rain than *M. avenae*. It was also noted that the rain had a minimal effect on predators and that adult parasites were emerging from the mummified aphids.

An insecticide treatment was not recommended when we met with the growers on the evening of June 21 because there was no evidence from our examination that kernels had been injured up to that time, the rain had substantially reduced aphid populations on the heads, and predators and parasites of aphids were active in the fields. This recommendation appears to have been correct; the treated and untreated plots had similar yields, 4197 and 4407 kg/ha respectively. These yields were not less than in plots of the previous year when there was no significant aphid infestation. Likewise the mean test weights of 70.9 for untreated and 71.0 kg/hl for treated plots were not statistically different. Nevertheless, we had some concern at the time because the amount of rainfall varied widely throughout the

county, with some areas receiving only one-half that recorded at the research station. However, there was a record high yield in the county of 4100 kg/ha and there were no test weight problems — a certain symptom of insect or disease damage.

Conclusions

Light to severe aphid infestations on the heads of winter wheat during the first half of grain filling did not reduce yields or test weight. A heavy, driving rain effectively reduced aphid populations and was a major factor in advising growers not to treat their fields. It was demonstrated that an application of malathion at the recommended rate would have provided effective control if a treatment had been necessary. The decision not to recommend an aerial application of insecticides saved the growers approximately \$25/ha. There were about 28,745 ha of winter wheat in Essex County in 1979.

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GROUND BEETLES IN THREE TILLAGE PLOTS IN ONTARIO AND OBSERVATIONS ON THEIR IMPORTANCE AS PREDATORS OF THE NORTHERN CORN ROOTWORM, *DIABROTICA LONGICORNIS* (COLEOPTERA: CHRYSOMELIDAE)

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Abstract

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Adults of 23 species of ground beetles (Coleoptera: Carabidae) were collected at Elora, Ontario, from corn fields (*Zea mays* (L.)) prepared with zero, minimum and full tillage. The six most numerous species, in a decreasing order of abundance were: *Pterostichus melanarius* Ill., *Clivina fossor* L., *Agonum muelleri* Hbst., *Bembidion quadrimaculatum oppositum* Say, *P. lucublandus* Say, and *Harpalus affinis* Schr. The seasonal abundance of these species in the three tillage systems were similar. The species most reduced in the full-tillage system were *A. muelleri*, *P. lucublandus*, and *H. affinis*.

Adults of *P. melanarius*, *C. fossor*, *A. muelleri*, *B. q. oppositum*, *Tachys* sp., *Trechus apicalis* Mts., *Harpalus pensylvanicus* DeG., and several carabid larvae became radioactive when confined with the natural fauna of soil samples including larvae of northern corn rootworm that were labelled with ³²P; and *Carabus nemoralis* Mull., *C. fossor*, and *P. melanarius* became radioactive when confined in similar free choice cages with rootworm eggs labelled with ¹²⁵I. Probably these beetles preyed on rootworms in the field.

Introduction

Predation and tillage are two factors that influence corn rootworm survival. The ground beetles (Coleoptera: Carabidae) *Pterostichus lucublandus* Say (Kirk 1971) and *Harpalus pensylvanicus* DeG. (Kirk 1973) were reported to feed on rootworms; and Musick and Collins (1971) speculated that numbers of rootworm larvae were smaller in a reduced-tillage system than in a conventionally-tilled system because the numbers of predators were greater. Musick and Collins' hypothesis is plausible because, according to Anderson and Huber (1972), the numbers of the predacious ground beetle, *Bembidion quadrimaculatum oppositum* Say, were greater in a minimum- than in a full-tillage system. Because the northern corn rootworm is a major pest of corn in Ontario and because knowledge of its natural controls is limited, it is important to investigate if the carabids occurring in Ontario are predators of rootworms and if reduced tillage favours their populations. Reported here is a list of the species of carabids found in corn fields at Elora, Ontario, a comparison of the species and numbers in three tillage regimes and some notes on their importance as predators of rootworm eggs and larvae.

Materials and Methods

Adjacent plots of corn prepared with zero, minimum, or full tillage as described by Tyler and Ellis (1974) were at the Ontario Ministry of Agriculture and Food Research Station at Elora, Ontario. The schedule of operations they described for the tillage systems, the seed treatments, and the herbicide and fertilizer applications were the same each year from 1970 to the spring of 1975

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with three exceptions. The plot with minimum tillage was not disced as thoroughly in 1974 as in other years because the ground had started to freeze. The corn in the plot with full tillage was harvested as silage in 1974 and not incorporated into the soil; and P.A.G. SXIII was the variety planted in the zero- and minimum-tillage plots while Funk's G4082 was planted in the full-tillage plot in 1975. Each tillage treatment contained four replicate-areas (56 x 30 m) and both the treatments and replicates were separated by 3-m strips that were without corn.

Adult carabids were collected from pitfall traps. These traps were 2.4-m eaves troughs closed at each end with end pieces and placed in the soil level with the soil surface. The traps were covered with plywood strips (0.2 x 2.6 m) that were held about 2 cm above the ground surface to keep out debris and rain but allow arthropods to enter. Water was never found in the traps. One trap was randomly positioned in each replicate-area and all traps reset every two weeks from 9 May until 8 Oct. Carabids that fell into these traps during a 48-hour period were collected by hand or with a portable vacuum, stored in 70% ethanol, and later sorted. The data were transformed with $\log_{10}(x + 1)$ for analyses of variance and the means compared with Duncan's new multiple-range test.

The predator-prey relationships between carabids and rootworm larvae and eggs were investigated by confining suspected predators with labelled rootworms. The larvae and eggs were previously labelled and were then placed into containers filled with soil and roots from the base of corn plants in the field. Organisms already in the soil were unlabelled and provided the predators with alternatives to radioactive rootworms for food. Although this experimental design reduced the forced feeding problem when predators are confined alone with prey, there was the disadvantage that secondary and primary predators could not be differentiated.

Rootworm larvae were labelled with ^{32}P by confining them in petri dishes for 48 hours with the roots of corn seedlings that had been immersed for 24 hours in a ^{32}P solution ($\text{Na}^{32}\text{PO}_4$ in HCl solution). The larvae were then rinsed in distilled water and twenty were placed into each of three containers (2000 cc) filled with the soil and corn roots. Twenty-four hours later, the insect fauna in the containers were supplemented with carabid adults and larvae (Table I) collected from pitfall traps. The containers were sealed and stored in an environmental chamber at $24 \pm 1^\circ\text{C}$ with a 16-hour photoperiod. After two weeks, the arthropods were recovered by washing the soil through a series of screens with openings of 2 mm, 425 μm , and 177 μm . The beetles and larvae were then rinsed with distilled water and preserved in 70% ethanol until their radiation could be determined. Single specimens also collected from pitfall traps but not exposed to ^{32}P were the controls. All organisms were removed from the ethanol, dried on filter paper, and placed into vials. An equal amount of a scintillation liquid, composed of toluene (liquid scintillation counting grade) and the fluors PPO (2,4-diphenyloxazole) and POPOP (p-bis- 2-[(5-phenyloxazole)] benzene), was then added to each vial. The contents of each vial were monitored for radiation with a liquid scintillation counter within two half-lives of ^{32}P .

Rootworm eggs were labelled with ^{125}I by immersing them for one hour in a solution of Na^{125}I in sodium thiosulphate. The eggs were rinsed with distilled water and 100 were placed in two containers filled with soil and roots. Adults and larvae of carabids were collected from pitfall traps and divided into three groups. The first group (Table I) was placed in the two containers 24 hours after the labelled eggs had been added. The containers were then sealed. The last two groups were used for controls. Individuals from one group were placed in separate containers with soil that was sterilized and contained no radioactive eggs. Because there was

TABLE I. A list of carabid species exposed in containers to radiolabelled rootworm eggs and larvae for 14 days and the number labelled.

Rootworm Stage Labelled	Carabid Species	Number Recovered	Number Labelled
Larvae with ^{32}P	Adults		
	<i>Agonum muelleri</i> Hbst.	1	1
	<i>Bembidion quadrimaculatum</i> <i>oppositum</i> Say	2	1
	<i>Carabus nemoralis</i> Mull.	1	0
	<i>Clivina fossor</i> L.	5	2
	<i>Harpalus pensylvanicus</i> DeG.	2	1
	<i>Pterostichus lucublandus</i> Say	2	0
	<i>P. melanarius</i> Ill.	9	5
	<i>Tachys</i> sp.	4	1
	<i>Trechus apicalis</i> Mts.	1	1
	Larvae (several spp.)	6	6
Eggs with ^{125}I	Adults		
	<i>Agonum muelleri</i> Hbst.	31	0
	<i>Bembidion quadrimaculatum</i> <i>oppositum</i> Say	2	0
	<i>Carabus nemoralis</i> Mull.	14	1
	<i>Clivina fossor</i> L.	3	2
	<i>Harpalus affinis</i> Schr.	1	0
	<i>Lasiotrechus discus</i> F.	1	0
	<i>Patrobus longicornis</i> Say	1	0
	<i>Pterostichus lucublandus</i> Say	18	0
	<i>P. melanarius</i> Ill.	16	2
	<i>Tachys</i> sp.	6	0
	<i>Trechus apicalis</i> Mts.	8	0
	Larvae (several spp.)	4	0

a possibility that the ^{125}I solution would diffuse from the eggs and contaminate the carabids, single specimens of *A. muelleri*, *C. nemoralis*, *C. fossor*, *P. lucublandus*, *P. melanarius*, *T. apicalis*, and *Tachys* sp., composing a second control group, were each sealed in a container with soil contaminated with radioactive rinse water. All containers were kept in a growth chamber maintained at $15 \pm 1^\circ\text{C}$ and with a 12-hour photoperiod. After two weeks, carabids were screened from the soil, rinsed in distilled water, and placed in separate vials. An equal amount of 70% ethanol was added to each vial and the radiation was monitored with an automatic gamma counter within one half-life of ^{125}I . Organisms with high counts were rinsed with distilled water and recounted.

Radiation counts in both experiments were adjusted for the decay of the isotopes by using standards and were expressed as counts per minute. The average counts per minute of each arthropod was compared with those of the control groups using Scheffe's Test (Guenther 1964).

Results and Discussion

Twenty-three species of carabids were collected from the pitfall traps (Table II) and 13 of these species were common to each tillage system; namely *Harpalus pleuriticus* Kby., *Notiophilus aquaticus* L. and the 11 species of Table II. *Pterostichus melanarius* Ill. was the most abundant composing 64% of the total number collected from each tillage regime (Tables II and III). This species attained maximum numbers in all tillage plots in July (Fig. 1A). The next most abundant

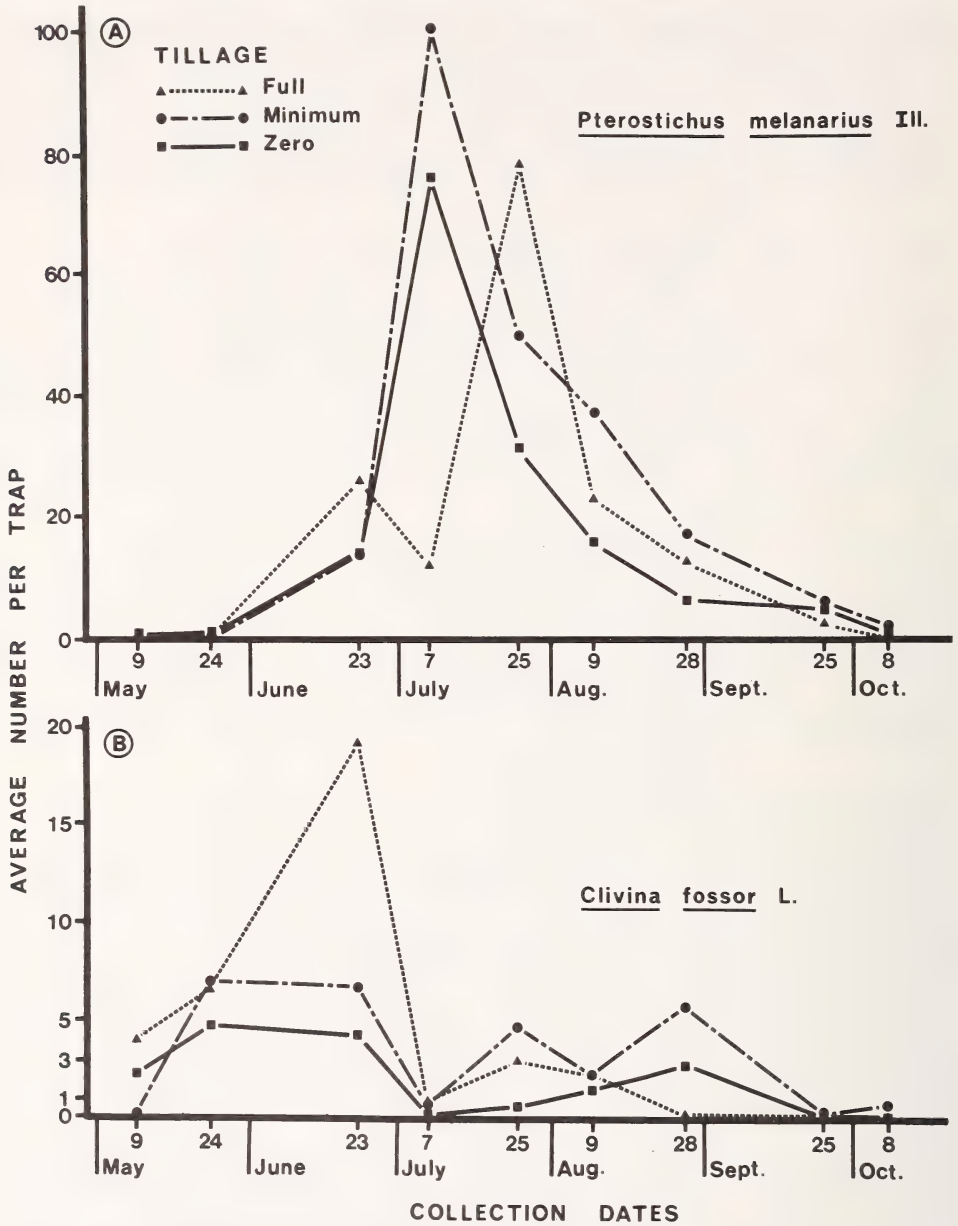


FIGURE 1. The seasonal abundance of adult carabids in corn fields under three tillage systems at Elora, Ont.: A, *Pterostichus melanarius*; B, *Clivina fossor*.

species were *Clivina fossor* L. (Fig. 1B), *Harpalus affinis* Schr. (Fig. 2A), *P. lucublandus* Say (Fig. 2B), *Agonum muelleri* Hbst. (Fig. 2C), and *Bembidion quadrimaculatum oppositum* Say (Fig. 2D). The seasonal abundance of these species in the three tillage systems were similar and maximum numbers were collected on the same dates in the three tillage systems. Instances when one species was statistically more abundant ($P \leq 0.05$) in one tillage system than the others are tabulated in Table IV. In general, *C. fossor* was more numerous in the tilled

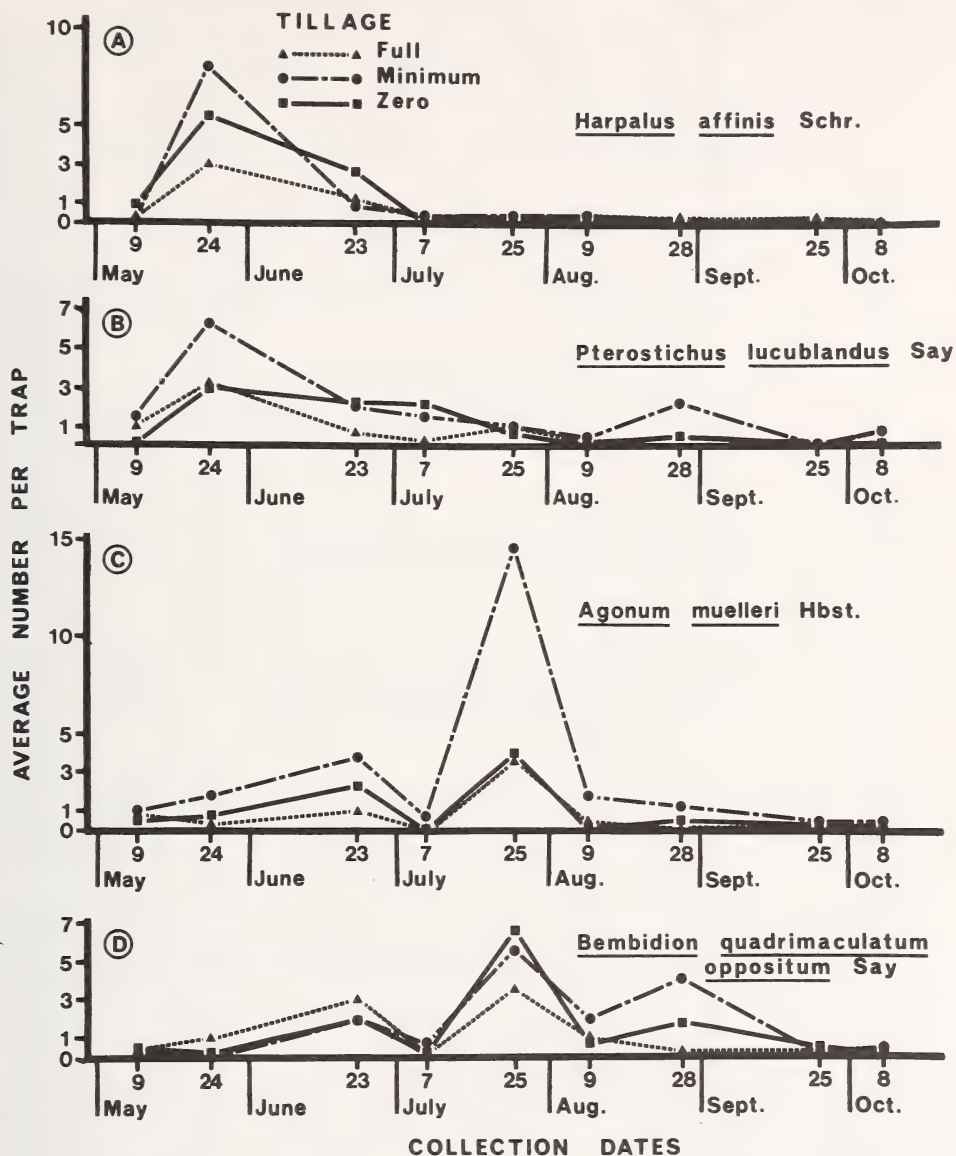


FIGURE 2. The seasonal abundance of adult carabids in corn fields under three tillage systems at Elora, Ont.: A, *Harpalus affinis*; B, *Pterostichus lucublandus*; C, *Agonum muelleri*; D, *Bembidion quadrimaculatum oppositum*.

systems (Fig. 1B) whereas *P. melanarius* was less numerous in the full-tillage system during maximum abundance in July (Fig. 1A). Full tillage resulted in generally lower numbers of *H. affinis* (Fig. 2A), *P. lucablanbus* (Fig. 2B), and *A. muelleri* (Fig. 2C). The differences between zero and minimum tillage were not consistent and, in fact, the total numbers collected in the minimum was greater than in the full tillage system (Table II).

A number of carabid adults and larvae became labelled ($P \leq 0.05$) when

TABLE II. Total numbers of adult ground beetles collected from May 9 to Oct. 8 from pitfall traps in a corn field under three management programs at Elora, Ontario.

Species	Tillage				Total
	Zero		Full		
	Number	% of total	Number	% of total	
<i>Pterostichus melanarius</i> Ill.	589	63.8	822	63.9	1960
<i>Clivina fossor</i> L.	62	6.7	106	8.2	294
<i>Agonum muelleri</i> Hbst.	31	3.4	99	7.7	155
<i>Bembidion quadrimaculatum</i>					
<i>oppositum</i> Say	48	5.2	58	4.5	142
<i>P. lucublandus</i> Say	33	3.6	60	4.7	122
<i>Harpalus affinis</i> Schr.	36	3.9	42	3.3	101
<i>Carabus nemoralis</i> Mull.	33	3.6	22	1.7	72
<i>Tachys</i> sp.	32	3.5	19	1.5	64
<i>Trechus apicalis</i> Mts.	15	1.6	8	0.6	45
<i>H. pensylvanicus</i> DeG.	18	2.0	14	1.1	33
<i>B. tetracolum</i> Say	6	0.7	6	0.5	18
Other ^a	20	2.2	31	2.4	64
Total	923		1287		3070

^a *Amara avida* Say, *Anisodactylus rusticus* Say, *Anisodactylus sanctaecrucis* F., *Bembidion versicolor* LeC., *Colliuris pensylvanica* L., *Dyschirius* sp., *Harpalus pleuriticus* Kby., *Lasiotrechus discus* F., *Notiophilus aquaticus* L., *Patrobus longicornis* Say, *Stenolophus comma* F.

TABLE III. Species composition of carabid adults collected in three tillage systems during 48-hr periods at Elora, Ontario.

Date	Tillage ^a System	<i>P.</i> <i>melanarius</i>	<i>C.</i> <i>fossor</i>	<i>A.</i> <i>muelleri</i>	<i>B.</i> <i>quadri-</i> <i>maculatum</i> <i>oppositum</i>	<i>P.</i> <i>lucublandus</i>	<i>H.</i> <i>affinis</i>	<i>C.</i> <i>memoralis</i>	<i>Tachys</i> sp.	<i>T.</i> <i>apicalis</i>	Other ^b
9 May	Z	2.4	21.4	4.8	4.8	0	9.5	7.1	28.6	2.4	19
	M	2.1	2.1	2.1	2.1	12.5	0	6.3	16.7	0	56.1
	F	5.0	40.0	7.5	5.0	5.0	2.5	5.0	17.5	0	7.5
24 May	Z	2.8	26.4	4.2	1.4	16.7	30.6	9.7	4.2	0	4.0
	M	0	24.6	6.1	1.8	21.9	28.1	7.9	0	0.9	8.7
	F	0	34.2	1.3	6.6	17.1	15.8	15.8	4.0	1.3	3.9
23 June	Z	36.9	10.9	5.8	5.0	8.4	6.7	11.7	10.1	1.7	2.8
	M	39.2	18.6	10.2	5.6	5.6	2.8	6.5	5.6	0	5.9
	F	49.5	36.7	1.8	5.5	1.2	2.4	0	0	2.4	0.5
7 July	Z	85.5	0.6	0	0.6	5.2	0	2.9	4.7	0	0.5
	M	88.6	1.4	4.3	1.1	2.1	0.7	1.1	0	0	0.7
	F	77.4	0.8	0	1.6	1.6	1.6	1.6	0	1.6	13.8
25 July	Z	66.8	2.1	8.6	13.9	1.6	0.5	1.6	1.1	1.1	2.7
	M	63.0	8.0	18.3	6.9	1.3	0.6	0	0	0	1.9
	F	85.8	4.2	3.8	3.8	1.1	0	0.3	0	0.3	0.6
9 Aug.	Z	76.1	9.1	0	3.4	0	1.1	0	0	3.4	6.9
	M	79.6	6.3	3.7	4.2	1.1	1.1	0	0	0	4.0
	F	81.9	10.3	1.7	3.4	0.9	1.7	0	0	0	0.1
28 Aug.	Z	40.6	23.8	3.2	11.4	3.2	0	0	1.6	3.2	13.0
	M	51.1	17.0	3.7	11.9	5.2	0.7	0	2.2	2.2	6.0
	F	82.0	1.6	0	1.6	3.3	1.6	1.6	0	4.9	3.4
25 Sept.	Z	60.7	0	3.6	7.1	0	0	3.6	0	3.6	21.4
	M	78.6	3.6	7.1	0	0	0	0	0	3.6	7.1
	F	60.0	0	6.7	6.7	0	6.7	0	0	13.3	6.6
8 Oct.	Z	31.7	0	0	0	14.3	0	0	0	42.1	26.2
	M	28.6	14.3	9.5	9.5	0	0	0	9.5	14.3	0
	F	11.5	0	3.9	7.7	11.5	0	0	11.5	38.5	15.4

^a Z — zero tillage; M — minimum tillage; F — full tillage

^b *Amara avida* Say, *Amara* sp., *Anisodactylus rusticus* Say, *Anisodactylus sanctaerucis* F., *Bembidion tetracolum* Say, *B. versicolor* LeC., *Colliuris pennsylvanica* L., *Dyschirius* sp., *Harpalus pleuriticus* Kby., *H. pennsylvanicus* DeG., *Lasiothreus discus* F., *Notiophilus aquaticus* L., *Parabus longicornis* Say, *Stenolophus comma* F.

TABLE IV. Dates when adults of any one species of carabids were more abundant in corn fields managed with either full, minimum or zero tillage.

Date	Species	Significant Differences ($P < 0.05$)
23 June	<i>Clivina fossor</i> L.	more numerous in the full- than in the zero- or in the minimum-tillage plots
7 July	<i>Pterostichus melanarius</i> Ill.	more numerous in the zero- and minimum- than in the full-tillage plot
25 July	<i>C. fossor</i>	more numerous in the full- and minimum- than in the zero-tillage plot
28 Aug.	<i>Bembidion quadrimaculatum oppositum</i> Say	more numerous in the minimum- than in the full-tillage plot
	<i>C. fossor</i>	more numerous in the minimum- than in the full-tillage plot

confined with radioactive rootworms (Table I). The apparent predacious nature of most of the carabid species in these experiments concurred with observations in the literature. *A. muelleri*, *B. q. oppositum*, *C. fossor*, *H. pensylvanicus*, *P. melanarius*, and *Trechus* spp. were reported to feed on immature stages of insect pests (Fox and MacLellan 1956; Wishart *et al.* 1956; Mitchell 1963; Johnson and Cameron 1969; Best and Beegle 1977 a, and b). Because of the experimental design we can conclude that the carabids that became labelled were either predators of rootworms or were involved in a food chain that included rootworms. Some of the ground beetles may have fed on labelled rootworm eggs and larvae but were no longer radioactive at the time of monitoring. *P. melanarius* became radioactive when confined with both larvae and eggs. Because a relatively high proportion of this species became labelled with ^{32}P and because it was the most

abundant carabid in all tillage regimes from July to the end of Sept., *P. melanarius* was the most influential carabid predator for reducing the numbers of rootworm larvae. *C. fossor*, the second most abundant carabid, also became radioactive from both eggs and larvae. However, because this species was significantly less abundant in the zero-tillage system, it probably had less impact as a predator of rootworms in this regime than in the minimum- and full-tillage regimes. All six carabid larvae became labelled with ^{32}P indicating they were active predators during the laboratory studies and may be in corn fields. In general, because more individuals and species were radioactive after confinement with the larvae than with the eggs, carabids are probably more important as predators of rootworm larvae in the field.

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A COMPARISON OF DEVELOPMENT AND FECUNDITY IN NORTH AMERICAN AND EUROPEAN POPULATIONS OF THE CEREAL LEAF BEETLE, *OULEMA MELANOPUS* (COLEOPTERA: CHRYSOMELIDAE)¹

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Abstract

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North American and European populations of the cereal leaf beetle, *Oulema melanopus* (L.) were observed side by side under controlled conditions. Beetles from North America were more fecund and after 10 months of storage oviposited over a longer period than European beetles even though total longevity did not differ. Duration of the egg stage at 5 constant temperatures was identical in both populations but larval development differed significantly at 17° and 31°C, suggesting adaptation to different temperature ranges in the two populations.

Introduction

In 1975, studies on the life system of the cereal leaf beetle, *Oulema melanopus* (L.) were initiated at Ottawa to determine, in part, its economic potential and environmental limits in Ontario. Because the insect was scarce and sporadic through most of its native range (Haynes 1973) its rapid spread in the U.S. mid-west and into Ontario during the 1960's suggested that a more vigorous strain may have developed in North America. Therefore, it was of interest to determine the factors that affect the fitness of the different populations. This is a report on some aspects of the comparative biology of beetle populations derived from Europe and North America and maintained at Ottawa under identical conditions during a two-year period.

Methods

Adults of *O. melanopus* were field-collected during the summer following pre-hibernation feeding by D. L. Haynes of Michigan State University at East Lansing, Michigan, and by K. P. Carl of the Commonwealth Institute of Biological Control, at Delémont, Switzerland. After roughly eight months of storage under conditions as described by Connin *et al.* (1968) the beetles of each population were released by the writer into separate ovipositional cages containing potted Laurier barley and held at 25°C and 60% R.H. with a 16:8h LD photoperiod. The barley seedlings, 10 to 15 cm high, were renewed daily and examined at intervals of 4-6 h during the daytime to obtain freshly laid eggs.

Developmental rates of the egg and larval stages were compared by side by side rearing of samples taken from each ovipositional cage, following the methods of Guppy and Harcourt (1978). Observations were made at 5 temperatures 17°, 22°, 25°, 27°, and 31°C using 50 to 100 eggs and not less than 30 larvae of each population.

For studies on the adult stage, individuals of each population were reared on potted barley under conditions as described above and the resulting adults stored at 5°C. Following 27, 35, and 42 weeks of storage, 10 sexual pairs of beetles,

¹Contribution No. 602 Ottawa Research Station, Agriculture Canada

from each colony each period, were caged individually in plastic cages (17 x 8 x 4 cm) and supplied with barley seedlings held in 25 ml vials. Mating frequency was recorded during two one-hour periods at mid-morning and mid-afternoon each day for 10 days. Eggs were counted every second day. Size of beetles was compared by measuring the length of the right elytron of all female beetles in these tests.

Data were compared using t-tests to determine statistical significance.

Results and Discussion

Development

The duration of the egg stage was the same for both the North American and the European populations at each of the five experimental temperatures (Table I). However, developmental time for the European larvae was significantly

TABLE I. Mean duration $\pm$ S.E. (days) of the egg and larval stages of two populations of *Oulema melanopus* at constant temperatures.

Stage and Population		Temperature ($^{\circ}$ C)				
		17	22	25	27	31
Egg	N.A.	11.3 $\pm$ 0.06	6.0 $\pm$ 0.07	4.9 $\pm$ 0.04	4.2 $\pm$ 0.03	3.8 $\pm$ 0.06
	EUR.	11.5 $\pm$ 0.10	6.0 $\pm$ 0.07	4.9 $\pm$ 0.03	4.2 $\pm$ 0.03	3.8 $\pm$ 0.07
Larva	N.A.	17.3 $\pm$ 0.27	10.3 $\pm$ 0.09	8.3 $\pm$ 0.12	7.2 $\pm$ 0.06	6.3 $\pm$ 0.12
	EUR.	16.5 $\pm$ 0.15	10.6 $\pm$ 0.15	8.1 $\pm$ 0.06	7.3 $\pm$ 0.13	6.9 $\pm$ 0.14
t-value ¹		2.86**	1.41	1.42	0.39	3.15**

¹For difference in larval development

**Significant at 1% level

shorter at 17 $^{\circ}$ C and longer at 31 $^{\circ}$ C than for the North American larvae. At 17 $^{\circ}$ C the difference in developmental time between the two populations was spread equally among all instars but at 31 $^{\circ}$ C this differential occurred mainly during instars 3 and 4. When the data were compared to rate of development curves as given by Guppy and Harcourt (1978) the rate for the North American larvae declined slightly at 31 $^{\circ}$ C as expected while that for the European larvae declined sharply. A decrease in the rate of development in response to increased temperature is a type of stress reaction to temperatures approaching the upper limit for an insect and it is often more evident in the later instars (Guppy and Mukerji 1974). Since response of both groups of larvae to the three intermediate temperatures was similar, the data suggest that the two populations differ in temperature limits only.

Fecundity

Table II shows that the numbers of eggs laid by laboratory reared females of the two populations after each of three storage periods was not significantly different even though the mean number laid by the North American beetles was consistently higher. However, standard errors were high due to using only 10 pairs of beetles per test. When the data from the 3 storage durations were pooled (Table II), the number of eggs laid by the North American beetles was significantly greater than that laid by the European beetles. Further evidence of this

disparity was indicated by the distribution in number of beetles classified by egg production categories as follows:

No. eggs laid	0-100	101-200	201-300	301-400
N.A. beetles	12	8	4	6
Eur. beetles	20	7	2	1

This difference in the number of eggs laid was observed in the original beetle populations received from Michigan and Switzerland when it became apparent

TABLE II. Fecundity of two populations of laboratory reared females of *Oulema melanopus*.

Mean number of eggs per beetle $\pm$ S.E.					
Test No.	Weeks Storage	N.A.	Eur.	Difference	t-value
1	27	186.3 $\pm$ 28.9	124.9 $\pm$ 31.3	61.4	1.15
2	35	196.3 $\pm$ 34.0	112.6 $\pm$ 26.8	83.7	1.93
3	42	126.0 $\pm$ 46.4	58.4 $\pm$ 20.5	67.6	1.20
Average		169.9 $\pm$ 22.1	102.4 $\pm$ 19.0	67.5	2.33**

**Significant at 1% level

that the European beetles laid fewer eggs after being placed into the oviposition cages. However, this may have been due partly to differences in pre-hibernation food quality or some other unknown factor affecting the beetles prior to storage. The results obtained from laboratory reared beetles indicate that true differences exist. There was no difference in elytral size between populations of laboratory reared female beetles from North America or Europe.

Oviposition activity and longevity

Following 27 weeks of storage the pre-ovipositional period for the European beetles was four days longer (Table III), but after storage periods of 35 and 42 weeks it was the same as that of North American populations. This indicates a

TABLE III. Mean number of days $\pm$ S.E. post-storage longevity and ovipositional activity of adult females of *Oulema melanopus*.

Weeks storage	Pre-ovipositional period	Ovipositional period	Post-storage life span
		N.A.	
27	5.5 $\pm$ 0.27**	29.4 $\pm$ 3.77	44.6 $\pm$ 5.41
35	4.0 $\pm$ 0.37	26.6 $\pm$ 3.50	41.0 $\pm$ 4.45
42	7.7 $\pm$ 1.08	22.2 $\pm$ 4.70*	37.8 $\pm$ 5.45
		Eur.	
27	9.8 $\pm$ 0.96**	23.1 $\pm$ 6.06	57.4 $\pm$ 9.7
35	5.3 $\pm$ 0.67	19.4 $\pm$ 3.69	52.7 $\pm$ 8.9
42	7.6 $\pm$ 0.57	11.9 $\pm$ 2.84*	50.1 $\pm$ 14.1

**t = 4.28, significant at 1% level

*t = 2.60, significant at 5% level

difference in requirements for hibernation. After 42 weeks of storage, length of the ovipositional period of European females was half as long as that of North American females. There was no significant difference between populations in overall longevity.

Mating behaviour

In the original stock, caged in lots of 50 to 70 beetles, the European beetles appeared to be more sedentary and mating appeared to be less frequent among these beetles than those from Michigan. However, in the laboratory reared populations there was no difference in the general activity level and feeding, nor was there a difference in mating frequency. Beetles of both groups generally mated twice per day and averaged about 9 matings in 10 days.

Conclusion

Since the origin of *O. melanopus* in North America is unknown, we cannot conclude from the data presented here that a biological strain of the insect has developed therein but only that one population in North America is different from one in Switzerland in terms of fecundity and temperature limits for larval development. The differences observed may be important adaptations of the life system of the two populations. These differences were readily detected and more profound ones may exist.

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SUSCEPTIBILITY OF *CULEX* SPP. AND *AEDE*S SPP. LARVAE (DIPTERA: CULICIDAE) TO TEMEPHOS AND CHLORPYRIFOS IN SOUTHERN ONTARIO

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Abstract

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At 19°C, 24-hr LC₅₀'s for fourth-instar *Culex pipiens* (L.), *Culex restuans* Theobald and *Aedes vexans* (Meigen) to temephos (Abate®) were 1.03, 1.15 and 3.00 ppb ($\mu\text{g/l}$), respectively. No evidence of resistance could be detected in *Culex* spp. larvae from sites treated repeatedly over three years with temephos (LC₅₀ = 0.92 ppb). At 14°C, 24-hr LC₅₀'s of fourth-instar *Ae. stimulans* (Walker), *Ae. euedes* Howard, Dyar and Knab, *Ae. canadensis* (Theobald) and *Ae. excrucians-fitchii* were 5.11, 2.47, 4.42 and 3.33 ppb, respectively. The 24-hr LC₅₀'s of *C. pipiens* and *C. restuans* fourth-instar larvae to chlorpyrifos (Dursban®) were 0.46 and 0.41 ppb, respectively, at 19°C.

Introduction

Following the 1975 outbreak of St. Louis Encephalitis, SLE, (Mahdy *et al.* 1979) many municipalities in southwestern Ontario initiated mosquito larviciding programs. Control efforts were directed primarily against *Culex pipiens*, the suspected vector of SLE in Ontario (Helson *et al.* 1980). Larval control of other species has also been undertaken because of their annoyance to humans or their potential as vectors of other arboviruses. Although chlorpyrifos (Dursban®) has been used by some municipalities (MacKenzie 1977) temephos (Abate®) has been used most commonly in Ontario.

Resistance of mosquito larvae to organophosphorous insecticides, including resistance to temephos and chlorpyrifos (Gillies *et al.* 1968b), can develop as a consequence of continuous extensive exposure (Georghiou *et al.* 1975). Consequently, it is important to regularly monitor the susceptibility of larval populations to determine if resistance is developing before control failures occur.

The susceptibility of species of mosquitoes most commonly being controlled in southern Ontario is presented in this paper. The only published data for mosquito susceptibility in southern Ontario is that by Brown *et al.* (1954) for DDT. Our data were collected from various regions of the province with no known history of insecticide treatment and are considered to represent unexposed populations. This study should provide baselines for future comparisons to determine if resistance is developing. Tests were also conducted on *C. pipiens* and *C. restuans* larvae collected from sites which had been treated at least 10 to 20 times with temephos from 1976 to 1978, to determine if resistance was developing.

Materials and Methods

Mosquito larvae were collected from natural breeding sites in various counties of southern Ontario, predominately Essex, Niagara and Wellington. In areas where *Culex* spp. larvae were being controlled few larvae could be collected from breeding sites. Consequently, oviposition pools (Surgeoner and Helson 1978) were placed immediately adjacent to treated sites. *C. pipiens* and *C. restuans* egg rafts and larvae were collected weekly from these pools, transported to the laboratory

at the University of Guelph and reared to 4th-instar for testing. Because resistance is a genetic phenomenon, populations adjacent to regularly treated sites should exhibit resistance if present.

In the laboratory, larvae were identified and 25, 4th-instars placed into a 200 ml Lab-Tek® plastic specimen container containing 199 ml of distilled water. Larvae of *Ae. fitchii* (Felt and Young) and *Ae. excrucians* (Walker) were not separated because of the handling and possible injury required to separate these species. A fresh 200 ppm (mg/l) stock solution of technical temephos (95.7%) or chlorpyrifos (99.0%) in 99, Mol % acetone was prepared before each test. Appropriate solutions were prepared by serial dilution so that 1 ml of solution when added to 199 ml of water provided the desired insecticide concentration. The 1 ml solutions were dispensed into each cup using a 1 ml Eppendorf® automatic pipette. The contents were stirred and covered with a cardboard lid to reduce evaporation.

Each concentration was tested against two or three groups of 25 larvae each. One ml of acetone was added to the controls. All larvae were then transferred to an incubator and held at $19 \pm 1^\circ\text{C}$ for the summer species and $14 \pm 1^\circ\text{C}$ for the spring species. These temperatures were selected as they represent water temperatures to which the 4th-instar larvae would be exposed in field situations in southern Ontario.

Mortality was assessed after 24 hr. Dead and moribund larvae were combined for mortality determinations. Larvae were considered moribund if unable to flex head to siphon when stimulated with a probe. Only tests with 3 to 5 concentrations, providing average mortalities between 10 and 90% were included. Tests with control mortalities greater than 20% or with greater than 10% pupation were excluded also. Results were analyzed by an APL probit analysis program based on Finney (1971) to provide 24-hr LC_{50} and LC_{90} values.

Results and Discussion

The LC_{50} and LC_{90} values for temephos (Table I) against *C. pipiens* larvae were similar to other studies, using a variety of techniques, from different areas of

TABLE I. 24-hr LC_{50} and LC_{90} (ppb) values for temephos using fourth-instar larvae of selected mosquito species collected in southern Ontario.

Species	Year	No. of Trials	Temp. °C	LC_{50}	95% CL*		LC_{90}	95% CL*	
					Lower	Upper		Lower	Upper
<i>C. pipiens</i>	1977	14	19	0.98	0.88	1.08	1.72	1.60	1.84
	1978	3	19	1.24	1.08	1.40	2.15	1.78	2.52
<i>C. restuans</i>	1977	7	19	1.21	1.05	1.37	2.27	1.96	2.58
	1978	3	19	1.03	0.79	1.27	1.92	1.02	2.82
<i>C. pipiens-restuans</i> (previously treated sites)	1978	12	19	0.92	0.80	1.04	1.70	1.43	1.97
<i>Ae. vexans</i>	1977	8	19	3.00	3.51	2.49	4.85	3.81	5.89
<i>Ae. stimulans</i>	1977	3	14	4.86	3.96	5.76	6.78	5.25	8.31
	1978	10	14	5.19	3.50	6.88	8.34	5.62	11.06
<i>Ae. euedes</i>	1978	6	14	2.48	2.03	2.93	4.65	3.57	5.73
<i>Ae. canadensis</i>	1977	1	14	4.42	—	—	9.59	—	—
<i>Ae. fitchii-excrucians</i>	1977	1	14	4.26	—	—	5.66	—	—
	1978	2	14	2.88	2.80	2.96	6.38	3.83	8.93

* Confidence limits of mean LC values.

the world (Anonymous 1970; Jones *et al.* 1976; Rettich 1976; Rettich 1977; Sinègre 1967; Sutherland 1971; Sutherland and Evans 1976). The mean LC_{50} value in those studies was 0.90 ppb with a range of 0.32-1.6 ppb and the mean LC_{90} was 1.61 ppb with a range of 0.54-2.8 ppb. The susceptibility of *C. pipiens* in Ontario was within this range. By contrast, values of *ca.* 100 ppb have been recorded for resistant populations of *C. pipiens* (Georghiou *et al.* 1975).

The ratio of the LC_{90} to LC_{50} value is indicative of the state of susceptibility in mosquito populations (Gillies *et al.* 1968a; Pelsue *et al.* 1972). Susceptible populations generally have an LC_{90} approaching but not exceeding twice the LC_{50} value. As the proportion of tolerant individuals increases in a population, the LC_{90}/LC_{50} ratio increases to greater than two. Eventually, when resistance is well established the LC_{90}/LC_{50} ratio again approaches two, due to elimination of susceptible individuals from the population. For field populations of *C. pipiens* in Ontario, the mean LC_{90}/LC_{50} ratios in 1977 and 1978 were 1.81 and 1.73, respectively, indicating a susceptible population. No larvae tested from various regions of the province demonstrated consistent ratios greater than two.

The likelihood of resistance in *C. pipiens* and *C. restuans* populations was evaluated further by collecting larvae from regions of Niagara and Essex Counties where larviciding had taken place as required in 1976, 1977 and 1978. LC_{50} and LC_{90} values for these larvae were not significantly different from populations without prior insecticide exposure. The LC_{90}/LC_{50} ratio of 1.84 was also indicative of a susceptible population.

The susceptibility of *C. restuans* populations to temephos was similar to that of *C. pipiens*. Values obtained for *C. restuans* (Table I) were slightly higher than those in two other studies where the LC_{50} value ranged from 0.30-0.49 ppb and the LC_{90} from 0.46-1.1 ppb (Jones *et al.* 1976; Sutherland and Evans 1976).

TABLE II. 24-hr LC_{50} and LC_{90} values (ppb) for chlorpyrifos using fourth-instar *Culex restuans* and *Culex pipiens* larvae collected in southern Ontario.

Species	Year	No. of Trials	Temp. °C	LC_{50}	95% CL*		LC_{90}	95% CL	
					Lower	Upper		Lower	Upper
<i>C. restuans</i>	1978	3	19	0.41	0.29	0.53	0.98	0.92	1.04
<i>C. pipiens</i>	1978	2	19	0.46	0.26	0.66	0.88	0.72	1.04

* Confidence limits of mean LC values.

As shown here (Table II) and in earlier studies (Sutherland and Evans (1976), Sinègre (1967) and Rettich (1977)) chlorpyrifos is more toxic than temephos to *C. pipiens* and *C. restuans*. Our results were similar to other studies which reported LC_{50} values ranging from 0.13 (Steelman *et al.* 1967) to 3.0 ppb (Mulla *et al.* 1966).

Ae. vexans was less susceptible to temephos than *C. pipiens* or *C. restuans* which agrees with Rettich (1977) and Sutherland and Evans (1976). The LC_{50} value of 3.00 ppb was slightly higher than that obtained by Rettich (1977) but may be explained by the fact that our studies were conducted at slightly lower temperatures (19°C vs *ca.* 22°C). The LC_{90}/LC_{50} ratio of 1.6 indicates that the *Ae. vexans* population was susceptible.

Spring *Aedes* spp. larvae were also less susceptible to temephos than *Culex* spp. LC_{50} values were higher than reported for *Ae. stimulans* in New Jersey (*ca.* 5

ppb as compared to *ca.* 1 ppb (Sutherland 1971)) and *Ae. canadensis* in New Jersey and Pennsylvania (4.4 ppb as compared to <1.5 ppb (Sutherland and Evans 1976; Jones *et al.* 1976)). We believe that the susceptibility values for *Ae. euedes* and *Ae. fitchii-excrucians* are the first to be reported in the literature. Again, the LC_{50}/LC_{50} ratios were less than two for those spring *Aedes* spp. tested more than twice.

The LC_{50} and LC_{50} values reported here generally agree with those of other studies. They are slightly higher for spring *Aedes* spp. and *Ae. vexans* but these differences are considered insignificant as Rettich (1976) has shown 2-3 fold difference in susceptibility of *C. pipiens* and *Ae. cantans* 4th-instar larvae of different sizes. Differences may also be explained by inherent variations in natural populations, differences in experimental and holding conditions. Marked differences in susceptibility of *Aedes* sp. larvae at different temperatures to temephos have been observed by the authors and will be reported elsewhere. Evidently, resistance of mosquito larvae to organophosphorous insecticides does not exist at present in southern Ontario. Results reported here should serve as baselines for future comparisons, if resistance is suspected.

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POPULATION CHANGES OF THE NORTHERN CORN ROOTWORM (COLEOPTERA: CHRYSOMELIDAE) AND CORN YIELD LOSSES IN SOUTHWESTERN ONTARIO

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Abstract

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Methods are described for estimating population density of eggs and larvae of the northern corn rootworm, *Diabrotica longicornis* (Say), and for assessing effects of larvae on yield of corn by comparing plots treated with soil insecticides with non-treated plots. Mean density of larvae in non-treated plots with areas ranging from 16-66 m² was 6.3/plant and mean loss in yield was 0.7 tonnes/ha from 1975-78. Soil treatments of 10% granular carbofuran and phorate applied at a rate of 1.0 kg ai/ha reduced rootworm populations by a mean of 2.9 larvae/plant and increased yield by 14.2%. Addition of superphosphate partly compensated for losses caused by rootworms. The insecticides had comparable efficacies. Dry soil conditions in 1978 were responsible for reductions in density of larvae and in efficacy of insecticides. Yield stimulation by carbofuran occurred at some sites in 1976. A regression equation based on density of larvae and weight of ears in 1977 indicated a loss in yield of 2.5%/larva. Measurements of larval density were less variable in 66 m² plots than in smaller ones, and samples in 22 m² plots of 8% of the area were less variable than those of 4%.

Introduction

The northern corn rootworm, *Diabrotica longicornis* (Say), is recognized as a pest of corn in southern Ontario (Ont. Ministry Agric. and Food 1974) but there is insufficient information on its economic importance and control. Bereza (1975) reported that the rootworm was becoming more abundant. Tyler and Ellis (1975) described the effects of different tillage systems on egg density and on emergence of adults, and indicated the need for further research on damage caused in full tillage fields. Establishment of the northern corn rootworm in Quebec (Guibord 1976) and the western corn rootworm, *Diabrotica virgifera* Le Conte, in Ontario (Foott and Timmins 1977) may lead to greater damage under Canadian conditions. In the United States, loss in yield has been related to density of rootworm populations, extent of lodging, and root damage rating (Chiang 1973). Apple *et al.* (1977) compared plots that were treated with granular carbofuran with non-treated checks in studies conducted in seven states from 1971-74 and reported significant overall losses in three states ranging from 7.5-25.5% of yield. These losses were associated with mean populations of 11.6-22.8 larvae/plant. Pimentel *et al.* (1978) found that mean densities ranging from 0.4 to 1.0 larvae/plant caused reductions in yield of 7-22% in New York State. Petty *et al.* (1969) estimated losses of 0.8% in high density and 1.4%/larva in low density populations. The object of this study was to describe larval populations of the northern corn rootworm and their effects on the yield of corn.

Materials and Methods

Field experiments to determine the effects of northern corn rootworm larvae on yield of corn were conducted in cooperation with growers. Plots were established on clay and clay-loam soils at various sites in southwestern Ontario from 1975 to 1978. The names and locations of sites were: Campbell and Dawson in

Kent, Harper and Selves in Perth, Oil City and Sharp in Lambton, and Stumpf in Middlesex county. Sites selected had been cropped to corn for at least two previous years (continuous corn), had lodging damage, and had a mean density of at least 2.0 rootworm eggs per kg of soil in the spring.

Soil samples for determining density of eggs were collected using a spade with a 15 x 20 cm blade or, when specified, a 6.3 cm i.d. x 15.0 cm high core sampler. The soil sample at a site consisted of one spadeful of soil taken from each of 25 locations to a depth of about 15 cm. The 25 subsamples were taken at intervals of 4 m with alternate left and right turns to the direction of travel. The subsamples from a site were mixed in the laboratory and eggs were extracted from soil units of one litre from soil that was held for two days at 20°C and about 65% RH. At least six units were examined for eggs and density was expressed as numbers per kg of soil. Eggs were separated from soil by sieves (Lawson and Weekman 1966) and magnesium sulfate flotation (Chandler *et al.* 1966; Matteson 1966). Eggs were counted using a binocular microscope. When the core sampler was used, two or three cores were collected between plants in the rows in June and numbers of eggs per kg of soil were recorded.

Plant roots and the associated soil for determining number of larvae were usually collected during the first two weeks of July. A block of soil about 23 cm in diameter and 15 cm deep was removed with each root system. Roots were washed and the soil was sifted through screens to remove larvae. Three to eight roots were sampled per plot with one or two being selected per row. Larvae of the northern and western rootworm were not distinguished in the larval counts. However, from observations on adult populations the western rootworm comprised about 1, 6, and 20% in 1976, 1977, and 1978 respectively.

Granular insecticides, carbofuran and phorate, were applied to the soil at planting through cone seeders attached to a 3-row International 185 planter. Granules were dropped in a 15 cm band over the seed furrow and covered with soil by dragging a heavy V-shaped chain behind the press wheel. The numbers of larvae and the yield in the treated plots were compared with those of non-treated checks.

Plots were of 4 sizes: about 16 m² (3 rows x 6 m); 22 m² (4 rows x 6 m); 44 m² (4 rows x 12 m) and 66 m² (6 rows x 12 m). Row spacing was 91 cm and plant density was reduced to about 25 plants/6 m of row when plants were 15 cm high. The treatments were replicated 3 to 6 times in randomized blocks.

Plots were planted in May and the practices of cooperating growers were followed in the application of fertilizers and herbicides. In 1975, these materials were experimental variables at Oil City where the level of soil phosphorous was low. They were applied by hand during planting at the following application rates: superphosphate, 67.0 kg/ha; lime, 100.0 kg/ha; and Sutan and atrazine at 4.0 and 1.0 kg/ha respectively.

Yields were determined by hand-harvesting the ears in October and were based on the weight of grain at 15.5% moisture of all plants or of plants in 1 or 2 rows per plot.

In 1977, relationships between the density of rootworm larvae at plots where 8 plants were sampled and various plant measurements were investigated at all sites. Height of ear from ground and per cent of plants with under-sized ears were measured on all plants in a plot about a week before harvest. In the laboratory, ear weight and per cent of plants with ears < 100 g dry weight were measured on corn harvested at 15.5% moisture from 2 rows/plot.

Data were analysed using analysis of variance, Duncan's Multiple Range Test, "t" test, and correlation and linear regression. When necessary, data were transformed using arc sin. Differences reported are for those that are significant at the 5% level unless otherwise stated. Means are expressed with standard errors.

Results and Discussion

The density of rootworm larvae at plots not treated with soil insecticides varied from 0.8 to 16.5 larvae/plant and yield varied from 2.0 to 9.1 tonnes/ha from 1975 to 1978. In 1975 at Oil City, all plots except those that were treated with carbofuran had high densities of rootworm larvae (Table I). Addition of

TABLE I. Effects of carbofuran, superphosphate, lime, and herbicides on populations of northern corn rootworm larvae, height of ear from ground, weight of fresh ear, and yield of corn (Pioneer 3909) at Oil City, Ontario in 1975.^a

Treatment	Rate of application of kg/ha	Larvae/plant ^b	Height of ear cm ^c	Weight of fresh ear, g ^c	Yield tonnes/ha
Carbofuran	1.0	0 a ^d	88.1 a ^d	263.6 a ^d	3.2 a ^d
Superphosphate	67.0	16.5 b	73.7 ab	204.1 b	2.8 ab
Lime	100.0	13.5 b	79.0 ab	212.6 ab	2.2 b
Sutan, atrazine	4 and 1	15.8 b	72.5 ab	198.4 b	2.1 b
Non-treated check		11.8 b	72.1 b	170.1 b	2.0 b

^a Mean number of eggs was 82.6/kg of soil. Planting and harvest dates were 25 May and 15 October respectively.

^b Means of 5 plants in each of 6 replicates of 44 m² plots on 16 July.

^c N = 30

^d Means in column followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

superphosphate compensated for the yield reduction of 1.2 tonnes/ha caused by rootworms at a density of 11.8 larvae/plant in check plots. This response to fertilizer was observed only at Oil City, and was probably attributable to the low level of phosphorus at this site in 1975.

In the 17 fields sampled at various sites from 1976-78, the density of rootworm larvae was significantly lower in treated than in non-treated plots in ten comparisons where carbofuran was used and in 11 where phorate was used. Yield was consistently higher in treated than in non-treated plots. Differences in yield were significant in four comparisons where carbofuran was used and in three where phorate was used. Pooling of the yearly data of the various sites usually resulted in a significant difference in yield.

Analysis of the combined data of the Harper, Oegema, Sharp and Stumpf sites in 1976 indicated that the densities of rootworm larvae in both 16 m² and 66 m² plots were significantly ($P < 0.01$) higher in non-treated check than in treated plots (Table II). Measurements of larval density were less variable in plots of 66 m² than in those of 16 m² (Table III). Plots that were treated with carbofuran and phorate did not differ significantly in larval density. However, the yield of plots that were treated with carbofuran significantly exceeded that of non-treated checks whereas those treated with phorate were similar to checks (Table II). Yield stimulation by carbofuran has been described by Apple (1971) and Daynard *et al.* (1975). Carbofuran and phorate reduced larval density by 64.0-75.0% in 1976 and the overall loss at non-treated plots was 0.7 tonnes/ha which amounted to 10.7-12.7% of the potential yield.

TABLE II. Mean population of rootworm larvae and yield of corn for plots treated with soil insecticides and for non-treated check plots for all sites in 1976.^a

Area of plot m ²	Treatment	Rate of application kg ai/ha	Larvae/ plant ^{b,c}	Yield tonnes/ha ^{b,d}
16	Carbofuran 10 G	1.5	2.5 <i>a</i>	7.1 <i>a</i>
16	Phorate 10 G	1.5	2.1 <i>a</i>	6.0 <i>b</i>
16	Check		9.2 <i>b</i>	5.8 <i>b</i>
66	Carbofuran 10 G	1.0	2.1 <i>a</i>	5.9 <i>b</i>
66	Phorate 10 G	1.0	1.5 <i>a</i>	5.1 <i>c</i>
66	Check		5.0 <i>b</i>	4.8 <i>c</i>

^a Sites and hybrids were: Harper, Sharp, and Stumpf with P.A.G. SXIII and Oegema with Pioneer 3909. Mean number of eggs were 3.0-10.4/kg of soil. Planting and harvest dates were 26-27 May, 7-26 October respectively.

^b Means were based on N = 8 for treated and N = 16 for non-treated 16 m² plots and N = 12 for 66 m² plots. Means in column followed by the same letter are not significantly different at the 5% level. Means within plot classes were compared using Duncan's Multiple Range Test and between classes using "t" test.

^c N = 4 plants/16 m² plot and N = 6 plants/66 m² plot.

^d N = 1 row/plot.

TABLE III. Density of rootworm larvae and the yield of corn for plots and samples of different sizes treated with soil insecticides and non-treated check plots in 1976 and 1977.

Treatment	Larvae/plant, mean and SE	Yield, tonnes/ ha, mean and SE
1976 ^a		
Carbofuran 10 G	2.5 ± 1.1	7.1 ± 0.7
Phorate 10 G	2.1 ± 0.5	6.0 ± 0.4
Check	9.2 ± 1.4	5.8 ± 0.4
1976 ^b		
Carbofuran 10 G	2.2 ± 0.9	6.6 ± 0.9
Phorate 10 G	2.0 ± 1.0	5.1 ± 0.5
Check	5.0 ± 0.6	4.8 ± 0.3
1977 ^c		
Carbofuran 10 G	1.6 ± 0.3	10.4 ± 0.9
Phorate 10 G	1.8 ± 0.4	10.8 ± 0.9
Check	4.5 ± 0.7	10.2 ± 0.9
1977 ^d		
Carbofuran 10 G	1.7 ± 0.2	9.9 ± 0.8
Phorate 10 G	2.3 ± 0.3	10.2 ± 0.7
Check	5.0 ± 0.6	8.7 ± 0.8

^a In 16 m² plots and means based on N = 8-16 with larval samples of 5% of plot area and yield samples of 33% of the crop.

^b In 66 m² plots and means based on N = 12 with larval samples of 2% of plot area and yield samples of 33% of the crop.

^c In 22 m² plots and means based on N = 16 with larval samples of 4% of plot area and yield samples of 50% of the crop.

^d In 22 m² plots and means based on N = 16 with larval samples of 8% of plot area and yield based on 50% of the crop.

Measurements of larval density in 22 m² plots using a sample that included 8% of the area were less variable than those using 4% (Table III). Analysis of the combined data of the Campbell, Dawson, Selves, and Sharp sites in 1977 indicated that the population density of corn rootworm larvae was significantly ($P < 0.01$) higher in non-treated check than in treated plots (Table IV). Plots treated with carbofuran and phorate were not significantly different from each other in larval density or yield but they significantly exceeded non-treated check

plots in yield (Table IV). Carbofuran and phorate reduced larval density by 60.6% in 1977 and the overall loss at non-treated plots was 1.0 tonnes/ha which amounted to 9.9% of the potential yield. Populations were not significantly different in 1978. Analysis of the combined data of the Campbell, Dawson, and Oil City sites in 1978 indicated that the density of larvae and yield were unaffected by the use of soil insecticides (Table IV). The low levels of rootworm populations and

TABLE IV. Density of rootworm larvae and yield of corn for plots^a treated with soil insecticides and for non-treated check plots for all sites in 1977 and in 1978.

Treatment	Rate of application kg ai/ha	Larvae/ plant ^{bc}	Yield, tonnes /ha ^{bd}
1977 ^e			
Carbofuran 10 G	1.0	1.7 <i>a</i>	9.9 <i>a</i>
Phorate 10 G	1.0	2.0 <i>a</i>	10.3 <i>a</i>
Check		4.7 <i>b</i>	9.1 <i>b</i>
1978 ^f			
Carbofuran 10 G	1.0	1.1 <i>a</i>	4.6 <i>a</i>
Phorate 10 G	1.0	1.1 <i>a</i>	4.4 <i>a</i>
Check		0.8 <i>a</i>	4.3 <i>a</i>

^a Plots were 22 m².

^b Means were based on N = 32 for 1977 and N = 12 for 1978; means in column followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

^c N = 4-8 plants/plot in 48 plots in 1977 and N = 4 plants/plot in 1978.

^d N = 2 rows/plot.

^e Sites and hybrids were: Campbell with Pioneer 3780A, Dawson and Sharp with Pioneer 3784; and Selves with Pioneer 3978. Mean numbers of eggs were 2.5-7.0/kg of soil. Planting and harvest dates were 11-20 May and 5-25 October respectively.

^f Sites and hybrids were: Campbell with P.A.G. SX 121; Dawson with United 134; and Oil City with P.A.G. SX 12. Mean numbers of eggs were 2.0-3.9/kg of soil. Planting and harvest dates were 11-23 May and 1-17 October respectively.

low yield in 1978 were probably caused by unusually dry soil conditions. Mihm *et al.* (1974) showed that contact moisture was necessary for egg hatching of the western corn rootworm and this probably also applies to the northern.

Substitution of the 1977 data for density of rootworm larvae in non-treated check and treated plots in the relationship between larval density vs ear weight (Table V) indicated a 7.4% reduction in potential yield in non-treated plots. More work is needed to separate the effects or interactions of corn rootworms and other adverse factors on ear weight, size, and height.

The results of investigations conducted from 1975 to 1978 on northern corn rootworm based on comparisons of plots treated with soil insecticides and non-treated checks showed that populations with a mean density of 6.3 larvae/plant were responsible for a mean loss of 0.7 tonnes/ha that amounted to 14.2% of the potential yield. Carbofuran and phorate treatments did not differ significantly in efficacy or in their capacity to increase yield of treated plots over checks. There were on average 2.9 fewer larvae/plant in treated plots and the yield was 0.7 tonnes/ha greater (Table VI).

Density of larvae and yield of corn varied widely depending on year and site. Mean density of larvae ranged from 0.8-11.8/plant and losses from 0-1.2 tonnes/ha. Depending upon local conditions, the mortality caused by carbofuran and phorate ranged from 0-100% and the mean was 59.9%. The density of rootworm larvae in southwestern Ontario was lower and the losses caused were about the

TABLE V. Relationships between plot variables including number of corn rootworm larvae per plant and various measurements on grain corn^a at the Campbell, Dawson, Selves, and Sharp sites in 1977.

Variables ^b	Slope	Intercept	Correlation coefficient ^c
Larvae vs ear weight, g	-5.50	223.37	-0.23*
Larvae vs ear height, cm	-1.16	93.29	-0.18
Larvae vs under-sized ears, %	2.27	4.41	0.39**
Ear height, cm vs ear weight, g	2.22	7.46	0.82**
Undersized ears, % vs ear weight, g	-2.37	233.50	-0.79**
Ear height, cm vs undersized ears, %	-0.63	67.98	-0.69**
Per cent plants with ears ≤ 100 g vs ear weight, g	-2.37	233.50	-0.80**
Per cent plants with ears ≤ 100 g vs ear height, cm	-0.77	98.38	-0.70**

^a Corn varieties were Pioneer 3780A, Pioneer 3784, and Pioneer 3978.

^b Number of pairs = 48.

^c * = significant at 5% and ** = significant at 1%.

same as reported for Nebraska, Wisconsin, and Missouri from 1971-74 by Apple *et al.* (1977). The density of larvae in southwestern Ontario was higher and the losses were similar to those reported for New York State by Pimentel *et al.* (1978). Individual plant data indicated that yield reduction in 1977 was about 2.5% / larva; this was greater than the 0.8-1.4% / larva reported by Petty *et al.* (1969) for Illinois.

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TABLE VI. Differences between non-treated check plots and plots treated with soil insecticides in number of corn rootworm larvae per plant and in yield at different sites from 1976-78.

Site	Decrease in no. of larvae/plant		Increase in yield in tonnes/ha	
	Carbofuran	Phorate	Carbofuran	Phorate
1976 in 16 m ² plots ^a				
Harper	—	3.3	—	1.0
Oegema	3.7	—	1.0	—
Sharp	10.3	—	1.0	—
Stumpf	—	10.2	—	0
1976 in 66 m ² plots ^b				
Harper	3.5	4.9	1.3	0.6
Oegema	2.3	2.1	0.6	0.2
Sharp	1.6	4.2	2.5	1.8
Stumpf	3.2	3.0	0.4	0.8
1977 ^c				
Campbell	5.4	5.2	0.4	0.7
Dawson	3.6	2.5	1.0	0.8
Selves	—0.7	0.5	—1.0	—0.1
Sharp	3.0	2.5	—	—
1977 ^d				
Campbell	5.0	4.3	1.2	1.0
Dawson	4.3	2.2	1.4	2.1
Selves	1.2	1.5	1.3	1.5
Sharp	2.5	2.8	0.9	1.3
1978 ^c				
Campbell	1.2	1.2	—0.2	—0.2
Dawson	—1.0	0	0.7	0.7
Oil City	0	—0.9	—0.2	—0.3
Mean	2.9	2.9	0.8	0.7

^a Differences are based on means with N = 4 plot replicates with larval samples of 5% of plot area and yield samples of 33% of the crop.

^b Differences are based on mean with N = 3 with larval samples of 2% of plot area and yield samples of 33% of the crop.

^c Differences are based on means with N = 4 in 22 m² plots with larval samples of 4% of plot area and yield samples of 50% of the crop.

^d Differences are based on means with N = 4 in 22 m² plots with larval samples of 8% of plot area and yield samples of 50% of the crop.

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MICROBIAL ISOLATIONS FROM *SITOPHILUS ZEAMAI* (COLEOPTERA: CURCULIONIDAE)

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Abstract

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In a study of the microflora of the maize weevil, *Sitophilus zeamais* Motschulsky, exterior surfaces, faeces, food source (soft wheat) and internal contents of the insects were examined. Of eighteen apparently different organisms isolated, only one, (*Bacillus* sp.) occurred consistently in adults; and only two (*Pseudomonas* spp.) in pupae and larvae. Isolates were considered not to be the microorganisms of the mycetome.

Introduction

The maize weevil, *Sitophilus zeamais* Motschulsky has a mycetome that harbors spiral and C-shaped microorganisms (Musgrave and Homan 1962). At pupation this mycetome breaks up and the microorganisms are found in the mesentera and the female gonads of adults (Buchner 1965; Murray and Tiegs 1935). Other organisms are occasionally observed in squashed tissues of these insects but these have not been examined in any detail. This paper reports on the characteristics and generic identity of bacteria isolated from *S. zeamais* using standard bacteriological procedures similar to those applied by Crawford *et al.* (1960) in isolating bacteria from *S. granarius*.

Materials and Methods

The Insects

Weevils were reared on Yorkstar whole wheat that was previously heated at 100°C for two hours to ensure the destruction of extraneous insect infestation. At no time was the wheat microbiologically sterilized. Insects were reared in ventilated jars at approximately 27°C and 76% relative humidity. Twenty-eight larvae, sixteen pupae and thirty adults were examined in a number of cultures over a period of six months.

Culture of the Microorganisms

Insects were surface-sterilized in a solution of Hyamine 2389 and water (1:75); adults for 60 seconds and immature stages for 30. These times were considered as the minimal required for surface sterilization and did not cause internal sterilization. Each was then washed twice for approximately 30 seconds in sterile distilled water. That the exteriors of the specimens were sterile was established by the absence of growth in a nutrient broth during a 72 hour incubation at room temperature. After the 72 hours, specimens in broths were aseptically crushed and incubated for a further 72 hours.

All developmental stages of the weevils were sampled for surface microorganisms. Adults were allowed to walk over the surface of nutrient agar in Petri plates. Nonsterilized adults, pupae and larvae were incubated in sterile nutrient broth. Eggs were obtained by aseptic removal from common oviducts with sterile forceps and transferred to tubes of sterile nutrient broth.

Bacteria were cultured from wheat samples, before and after use as insect food, by transferring kernels to tubes of nutrient broth and to surfaces of nutrient agar in Petri plates, followed by incubation at room temperature. Attempts were made to culture faecal microbiota by allowing non-surface sterilized adults to walk over the surface of sterile nutrient agar in Petri plates for approximately one hour. Bacteria thus isolated were compared with those isolated from wheat samples and surfaces of adult weevils to determine the microbiota of faeces or other secretions.

Growth in broths or on agar plates was subcultured by streaking on the surface of nutrient agar plates. Individual colonies were selected and purified by repeated streaking onto nutrient agar plates.

Bacteriological Tests

For each purified culture of bacteria isolated from the food, faeces or exterior or interior of weevils, the following characteristics were determined: form, arrangement, size, Gram reaction, motility, odour, presence of endospores, colony chromogenesis and morphology, and soluble pigment production. Isolates from the interiors of weevils were subjected to the following additional tests; reactions: citrate, indole, Voges-Proskauer, nitrate and thiosulphate reduction; digestions: gelatin liquifaction, amygdalin, arabinose, glucose, inositol, mannitol, melibiose, rhamnose, sorbitol, sucrose; enzymes: arginine dehydrolase, Betagalactosidase, catalase, lysine decarboxylase, ornithine decarboxylase, oxidase, tryptophane deaminase, and urease (Buchanan and Gibbons 1974).

Results

Initially, the general characteristics and abundance of all the bacteria isolated were noted. Sixteen apparently different forms were isolated from the interiors of adults. Twelve of these forms were chromogenic and coccoid, characteristics displayed by a large proportion of the bacteria isolated from wheat and were, therefore, not studied further. Three other coccoid bacteria also resembling those from wheat were isolated from only two insects and were therefore also discarded. The remaining bacterium was isolated from twenty-nine of thirty specimens and was identified as *Bacillus* sp. (Buchanan and Gibbons 1974). These gram-positive, non-motile rods, often in chains, measured approximately $0.8 \times 2.0 \mu\text{m}$, liquified gelatin, reduced nitrates and were catalase positive. Endospores were frequent especially in aging cultures.

Two species of *Pseudomonas* (Buchanan and Gibbons 1974) were isolated from interiors of both pupae and larvae. One form was isolated from six of twenty-eight larvae and all of sixteen pupae, the other form from twenty-six of twenty-eight larvae and six of sixteen pupae. Both these forms were studied further. They were gram-negative, motile rods with a single polar flagellum. The species predominating in pupae measured approximately $0.5 \times 1.5 \mu\text{m}$, was catalase and Voges-Proskauer positive. The species predominating in larvae measured approximately $0.5 \times 1.2 \mu\text{m}$, was catalase, oxidase, lysine decarboxylase, urease and Voges-Proskauer positive and utilized citrate.

Two species of *Pseudomonas* identical to those isolated from the other immature stages were isolated from the insect egg before deposition. Both *Bacillus* sp. and *Pseudomonas* spp. were isolated from faeces of non-sterilized adults which had walked on nutrient agar. Seven species of bacteria different than those isolated from interiors of insects were isolated from surfaces of adults, three from surfaces of pupae and two from surfaces of larvae. These forms appeared to be normal

wheat flora for reasons outlined earlier (e.g. chromogenesis). Fungi were isolated from the surfaces of adults but not from the exteriors or interiors of the immatures.

None of the three bacteria isolated from the interior of larvae and pupae or from egg surfaces of the weevil was isolated from the wheat. The twelve different bacteria isolated from the wheat were either highly pigmented, coccoid or both. All were typical of bacteria found in association with dry plant matter (James 1955; Obsent'yan and Polonoskaya 1964) and were different from the three isolated only from the insects. They were not studied further.

Discussion

It seemed appropriate to distinguish between those microorganisms isolated from the wheat that were also isolated from the insects and those isolated from the insects that were not isolated from wheat. On this basis three microorganisms were categorized as a part of the microbial flora of *S. zeamais*.

Of the bacteria isolated, only one, *Bacillus* sp., was of the same genus as those previously reported from the granary weevil, *Sitophilus granarius* (L.) (Crawford *et al.* 1960).

Various species of *Pseudomonas* have been isolated from insects (Bucher and Stephens 1959; Steinhaus 1941). *Pseudomonas* spp. were not isolated from interiors of adult *S. zeamais* but were isolated from the exterior of eggs removed from common oviducts and from plates on which adults had walked. These latter isolations may have been derived from faeces, secretions of the gonads or the general body surfaces, though broth cultures indicated that body surfaces were free of pseudomonads.

The apparent absence of *Pseudomonas* spp. in adults may be the result of incidental sterilization of the common oviduct during Hyamine treatment. Moreover, the presence of so few pseudomonads in the female gonad may preclude their *in vitro* culture. The isolation of *Bacillus* sp. only from adults and their faeces suggests that the *Bacillus* is acquired only by the imaginal insect. Presumably the *Bacillus* resists digestion.

The presence of additional flora should be considered when isolating mycetomal microorganisms from *S. zeamais*, however there was no evidence that any of the isolated microorganisms originated from the mycetome.

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**EFFECTS OF *NOSEMA DISSTRIAE*
(MICROSPORIDA) ON THE FOREST TENT
CATERPILLAR, *MALACOSOMA DISSTRIA*
(LEPIDOPTERA: LASIOCAMPIDAE)**

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Abstract

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Spores of the microsporidium *Nosema disstriae* were fed to larvae of the forest tent caterpillar, *Malacosoma disstria* Hübner. The microsporidian adversely affected pupal weights, adult fecundity and longevity.

Introduction

Field populations of the forest tent caterpillar are often naturally infected with the microsporidium *Nosema disstriae* and infection levels are usually highest in the oldest infestations. The microsporidian parasite of the forest tent caterpillar was first described by Thomson (1959). In the present work tests determined the effects of this parasite on larval and pupal mortality, pupal and adult longevity, and ovarian development.

Materials and Methods

Tent caterpillars used in this study were obtained from field collected egg masses and were reared at room temperature (21-23°C) and a relative humidity of 40-60%. A few larvae were naturally infected with a nuclear polyhedrosis virus. Second and 4th-instar larvae were used in all tests. The insects were reared in 28.4 ml plastic cups, the surface area of the diet being approximately 4.7 cm² (Grisdale 1973). The diet surface was treated with 0.5 ml of an aqueous suspension of *N. disstriae* resulting in 3×10^4 , 3×10^6 or 3×10^8 spores per cup. Controls were treated with distilled water. Eight to 10 larvae were placed in each cup and allowed to feed on the treated diet for 96 hr., after which time the larvae were removed and placed on fresh untreated diet. The cups were checked every other day to ensure that the diet surface was free of fungal contamination. As the insects grew additional cups were used with fewer in each to allow more space. With the onset of pupation the tests were checked daily for pupae, which were sexed using the method of Muggli (1974) and weighed within 24 hr. The duration of the pupal stage and the longevity of adults were recorded. Earlier attempts at individual matings were not successful as few egg masses were produced; thus it was decided to count eggs within the female ovaries as an indication of fecundity.

Results and Discussion

The effects of feeding various dosages of *N. disstriae* spores to 2nd-instar forest tent caterpillars are shown in Table I. Increasing spore dosage resulted in a corresponding increase in larval mortality. The mortality in the controls was attributable to a natural infection of a nuclear polyhedrosis virus. Most of these natural infections showed up early and any cups containing infected insects were discarded. Table I also shows the effects of feeding spores to 4th-instar larvae.

TABLE I. Effects of feeding *Nosema disstritae* spores to 2nd- and 4th-instar larvae, on the biology of the forest tent caterpillar.

Instar	Dosage spores	% larval mortality ^a	Mean pupal weight (mg) per insect		Mean pupal stadium in days		% pupal mortality	Mean imaginal stadium in days		Mean number of eggs per female
			male	female	male	female		male	female	
II	0	47.6(86) ^b	258.6(18)	425.5(16)	14.3(18)	13.8(16)	—	6.2(18)	4.7(10)	152 (7)
	3 x 10 ⁴	69.4(69)	227.1(4)	349.1(4)	16.0(3)	14.6(3)	—	5.3(3)	3.5(2)	120 (2)
	3 x 10 ⁸	100 (67)	—	—	—	—	—	—	—	—
	3 x 10 ⁶	100(79)	—	—	—	—	—	—	—	—
IV	0	32.5(80)	233.0(25)	391.9(23)	13.6(25)	13.7(23)	11.1	5.1(25)	6.4(18)	148.6(11)
	3 x 10 ⁴	26.7(81)	235.3(18)	387.1(18)	13.7(18)	14.3(15)	17.5	4.7(18)	5.7(13)	97.5(5)
	3 x 10 ⁸	49.8(74)	218.8(9)	348.2(9)	14.2(9)	14.8(8)	28.0	5.7(9)	3.5(8)	58.0(5)
	3 x 10 ⁶	98.1(86)	—	—	—	—	100.0	—	—	—

^a Percentage larval mortality was adjusted for control mortality using Abbott's formula.

^b Number of individuals used in calculations is shown within parentheses.

Again there was increased larval mortality with the higher spore dosages. At all dosages, mortality of the 2nd-instar larvae was higher than that in the 4th-instar larvae. In both cases, there was a decrease in mean pupal weights and mean number of eggs per female with the higher spore dosage. Some caution has to be taken when interpreting the results due to virus infection that may have been overlooked. However, differences from the controls have to be attributed to the microsporidian parasite.

In a preliminary test, Wilson (1977) reported that feeding 2nd-instar tent caterpillars on a diet treated with 5×10^7 *N. disstriae* spores per cup resulted in 83% larval mortality with the remainder of the insects dying in the pupal stage. This experiment reported mortality for 2nd-instar larvae only. In the present test, 3×10^6 spores produced 100% mortality in the 2nd-instar larvae, this may have been partly due to the presence of the nuclear polyhedrosis virus (Stairs 1964). Based on the above observations, *N. disstriae* should be considered as a potential biological control agent for the forest tent caterpillar.

Acknowledgment

The technical assistance of Miss E. Young is gratefully acknowledged.

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SPECIES LIST OF ACARI RECOVERED FROM SOIL OF A GUELPH CORNFIELD AND A LONDON PASTURE¹

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Abstract

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Soil cores taken from a southwestern Ontario cornfield and pasture were extracted to determine their mite content. Mites were identified to genus and species where possible. The cornfield yielded 37 species from 29 families and the pasture 39 species from 26 families. One family (Prostigmata: Dolichocybidae) has been reported only once before from Canada; *Terpnacarus glebulentus* Theron (Prostigma: Terpnacaridae) and *Tarsonemus* sp. near *virgineus* Suski are reported for the first time in Canada.

Introduction

During 1977-1979, we undertook studies to determine the effect of soil arthropods on breakdown of leaf litter in an intensively cultivated cornfield and an annually mown pasture. These results will be published elsewhere. However, in this study resident soil mites were identified including those not involved in the breakdown of leaf litter. Presented here is an extensive list of the acarine species that were found in two agricultural soils of southwestern Ontario.

Materials and Methods

Soil cores (5 cm diam x 15 cm deep) were removed from random areas of experimental plots in an Arkell, Ontario cornfield and a London, Ontario pasture at various times during 1977, 1978 and 1979. The arthropods in the soil cores were extracted by modified Berlese-Tullgren funnels as described by Tomlin (1977). Arthropods were collected and preserved in ethanol:water:glycerol (70:25:5), and acarine specimens sorted and identified to suborder. Selected mite specimens were mounted in Heinze-PVA medium on glass microscope slides and viewed under a compound microscope for further identification to family or genus.

Results and Discussion

The Arkell cornfield yielded 37 species from 29 families (Table I), while the London pasture yielded 39 species from 26 families (Table II). Usually species were undetermined when only immature stages were available that could not be keyed out. A total of 33 different families were recovered and 22 of these were common to both sites. Two notable prostigmatid mites were collected from the cornfield soil. One was *Pavania* sp. (Dolichocybidae), one specimen of which was found September 1, 1978. This is only the second Canadian record of this family, the other being from tree nursery litter in Saskatchewan (Lindquist 1979). The other was *Terpnacarus glebulentus* Theron (Terpnacaridae), 2 specimens of which were found on August 3, and a further 2 specimens on September 1, 1978. Subsequently 3 more specimens of *T. glebulentus* were identified from

¹ Contribution No. 794, Research Institute, Agriculture Canada, London, Ontario; reprints available here.

TABLE I. Soil Acari collected from an Arkell, Ontario cornfield (1977-79)

Suborder	Family	Genus (and species where determined)
Prostigmata	Alicorhagiidae	<i>Alicorhagia</i> sp. undet.
	Bdellidae	<i>Spinibdella</i> sp. near <i>cronini</i> (Baker & Balock)
	Dolichocybidae	* <i>Pavania</i> sp. undet.
	Ereynetidae	<i>Ereynetes</i> sp. undet.
	Eupodidae	<i>Eupodes</i> sp. undet.
		* <i>Claveupodes</i> sp. near <i>delicatus</i> Strandt. & Prasse
	Nanorchestidae	<i>Speleorchestes</i> sp. undet.
	Pygmephoridae	<i>Bakerdania</i> sp. near <i>kochi</i> (Krczal)
	Rhagidiidae	<i>Rhagidia</i> sp. undet.
	Scutacaridae	* <i>Imparipes</i> (<i>Archidispus</i>) sp. near <i>minor</i> Karafiat
		<i>Scutacarus</i> sp. near <i>pratensis</i> Mahunka
	Tarsonemidae	<i>Tarsonemus</i> sp. near <i>confusus</i> Ewing
	Terpnacaridae	* <i>Terpnacarus glebulentus</i> Theron
	Tetranychidae	<i>Tetranychus canadensis</i> McGregor
	Tydeidae	<i>Tydeus</i> sp. in <i>kochi</i> group
Mesostigmata		<i>Coccotydaecolus</i> sp. undet.
	Ameroseiidae	* <i>Ameroseius</i> sp. near <i>cavernosus</i> Westerboer
	Ascidae	<i>Arctoseius cetratus</i> (Sellnick)
		<i>Protogamasellus primitivus</i> Karg
	Digamasellidae	* <i>Dendrolaelaps</i> sp. near <i>zwoelferi</i> Hirschmann
	Eviphididae	* <i>Alliphis</i> sp. near <i>siculus</i> (Oudemans)
	Laelapidae	<i>Hypoaspis aculeifer</i> (Canestrini)
	Pachylaelapidae	* <i>Pachyseius</i> sp. undet.
	Parasitidae	<i>Pergamasus mirabilis</i> Willmann
	Rhodacaridae	<i>Rhodacarellus</i> sp. near <i>perspicuus</i> Halaskova
Astigmata	Uropodidae	genus undet. (nymph)
	Acaridae	<i>Acarus farris</i> (Oudemans)
Cryptostigmata		<i>Rhizoglyphus echinopus</i> (Fumouze & Robin)
	Cosmochthoniidae	<i>Cosmochthonius</i> sp. undet.
	Epilohmanniidae	* <i>Epilohmannia</i> sp. near <i>styriaca</i> Schuster
	Euphthiracaridae	<i>Euphthiracarus</i> sp. undet.
	Oppiidae	<i>Oppia</i> sp. near <i>minor</i> (Paoli)
		<i>Oppiella</i> sp. undet.
		* <i>Lasiobelba</i> sp. undet.
	Oribatulidae	<i>Schelorbates</i> sp. undet.
		<i>Zygoribatula</i> sp. undet.
	Tectocepheidae	<i>Tectocepheus</i> sp. undet.

* Specimens deposited at the Canadian National Collection in Ottawa.

collections made at the London site on November 23, 1977, and April 17 and August 25, 1978. *T. glebulentus* has an unusual pattern of dorsal scales, and was recently recorded for the first time in North America by McDaniel and Theron (1979) in South Dakota.

Two specimens of a species of Tarsonemidae (Prostigmata) not previously known in Canada were collected from the London pasture soil on August 25, 1978. This species is closely related to or the same as that described by Suski (1969) as *Tarsonemus virgineus*, which is characterized by the presence of a flange on tibia II of adult females.

Specimens of all Acari listed in Tables I and II were deposited in the collection of soil Acari at the Research Institute, Agriculture Canada, London except for the 20 asterisked specimens which were deposited at the Canadian National Collection in Ottawa.

TABLE II. Soil Acari collected from a London, Ontario pasture (1977-79)

Suborder	Family	Genus (and species where determined)
Prostigmata	Alicorhagiidae	<i>Alicorhagia fragilis</i> Berlese
	Ereynetidae	<i>Ereynetes</i> sp. undet.
	Eupodidae	<i>Eupodes</i> sp. undet.
		* <i>Claveupodes</i> sp. undet.
	Nanorchestidae	<i>Nanorchestes</i> sp. undet.
	Microdispidae	* <i>Brennandania</i> sp. near <i>silvestris</i> (Jacot)
	Pygmephoridae	<i>Bakerdania quadrata</i> (Ewing) (=sellnicki Krczal)
		* <i>Bakerdania</i> sp. near <i>exigua</i> Mahunka
		<i>Siteroptes</i> sp. undet.
	Rhagidiidae	<i>Coccorhagidia</i> sp. undet.
		<i>Rhagidia</i> sp. undet.
	Scutacaridae	* <i>Scutacarus eucomus</i> (Berlese)
		* <i>Scutacarus</i> sp. near <i>kassaii</i> Mahunka
Mesostigmata	Tarsonemidae	<i>Tarsonemus</i> sp. undet.
		* <i>Tarsonemus</i> sp. near <i>virgineus</i> Suski
	Terpnacaridae	<i>Terpnacarus glebulentus</i> Theron
	Tydeidae	<i>Coccotydaecolus</i> sp. undet.
		<i>Tydeus</i> sp. undet.
	Ascidae	<i>Gamasellodes bicolor</i> (Berlese)
	Digamasellidae	<i>Dendrolaelaps (Dendrolaelaspis) angulosus</i> (Willmann)
	Laelapidae	<i>Hypoaspis aculeifer</i> (Canestrini)
		* <i>Hypoaspis</i> sp. near <i>angusta</i> Karg
		<i>Hypoaspis</i> sp. near <i>kargi</i> Costa
	Macrochelidae	<i>Macrocheles</i> sp. near <i>insignitus</i> Berlese
	Pachylaelapidae	<i>Pachyseius</i> sp. near <i>humeralis</i> Berlese
	Parasitidae	* <i>Pergamasus mirabilis</i> Willmann
Astigmata	Rhodacaridae	* <i>Rhodacarellus</i> sp. near <i>silesiacus</i> Willmann
	Acaridae	<i>Rhizoglyphus echinopus</i> (Fumouze & Robin)
		<i>Tyrophagus putrescentiae</i> (Schrank)
Cryptostigmata	Anoetidae	<i>Histiostoma</i> sp. undet.
	Brachychthoniidae	<i>Brachychthonius</i> sp. near <i>immaculata</i> Forsslund
		<i>Liochthonius</i> sp. near <i>lapponicus</i> (Tragardh)
	Cosmochthoniidae	<i>Cosmochthonius</i> sp. near <i>lanatus</i> (Michael)
	Euphthiracaridae	<i>Euphthiracarus</i> sp. undet.
	Oppiidae	* <i>Oppia</i> sp. near <i>heterotricha</i> Bernini
		<i>Oppia</i> sp. near <i>insculpta</i> Paoli
		<i>Oppiella</i> sp. near <i>nova</i> (Oudemans)
	Oribatulidae	<i>Scheloribates</i> sp. undet.
	Tectocephidae	<i>Tectocephus</i> sp. undet.

* Specimens deposited at the Canadian National Collection in Ottawa.

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**TOTAL PROTEIN AND AMINO ACID CONTENT OF THE GUT OF
NEODIPRION SERTIFER
(HYMENOPTERA: DIPRIONIDAE) DURING METAMORPHOSIS**

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During metamorphosis of the female European pine sawfly, *Neodiprion sertifer* (Geoff.), amino acid content of the gut attains the highest levels in the pupa; after the onset of adult development and egg production it declines, increasing again during the formation of meconium (Fogal and Kwain 1974). The pupal gut also contains a gel-like material which liquifies during adult development and is replaced by meconium. Hence, it is replete with other substances as well as amino acids which may be utilized for development of adult tissues. Protein is a likely constituent. To determine if egg production in females imposes an extra drain on the pool of material over and above that imposed by males, proteins and amino acid content were determined in both sexes during metamorphosis.

Cocoons were collected, stored and incubated as described earlier (Fogal and Kwain 1974). Amino acid and protein contents were determined in the guts of larvae, pupae and adults at developmental stages previously described (*ibid*) on six lots of four guts from males or females. Following dissection, guts were emptied into 0.1 ml of Ringer solution in a depression slide. This solution was then transferred to a small test tube and centrifuged. Amino acid content of the supernatant was determined with ninhydrin in an aliquot according to the method of Rosen (1957) using glycine (The British Drug Houses Ltd.) as standard. Total water soluble protein was determined in a second aliquot with the microbiuret reagent (Legget-Bailey 1967) using bovine serum albumin (Nutritional Biochemicals Corporation) as the standard.

Factorial analysis of variance of the data indicated that differences among stages and between sexes were highly significant. Differences between stages were tested with Duncan's multiple range test at the 5% level of probability and differences between sexes at certain stages were tested with the t-test at the 5% level of probability.

At all stages of development, gut amino acid content tended to be higher in females than in males (Figure 1a). In both sexes it remained relatively low during pupal development (stages 1-3). There was a sharp increase in the pupa (stage 4) followed by a drop during the initial stages (stages 5 and 6) of adult development. As the meconium formed in stages 7 and 8, amino acids increased.

Protein content also tended to be higher in females than in males (Figure 1b). In both sexes there was a slight increase up to stage 3 and a sharp increase in the pupa (stage 4). In female pupae the increase was significantly greater than in males and was followed by a decrease in stages 5 and 6 with an increase in stages 7 and 8. In males, protein content did not drop following the onset of adult

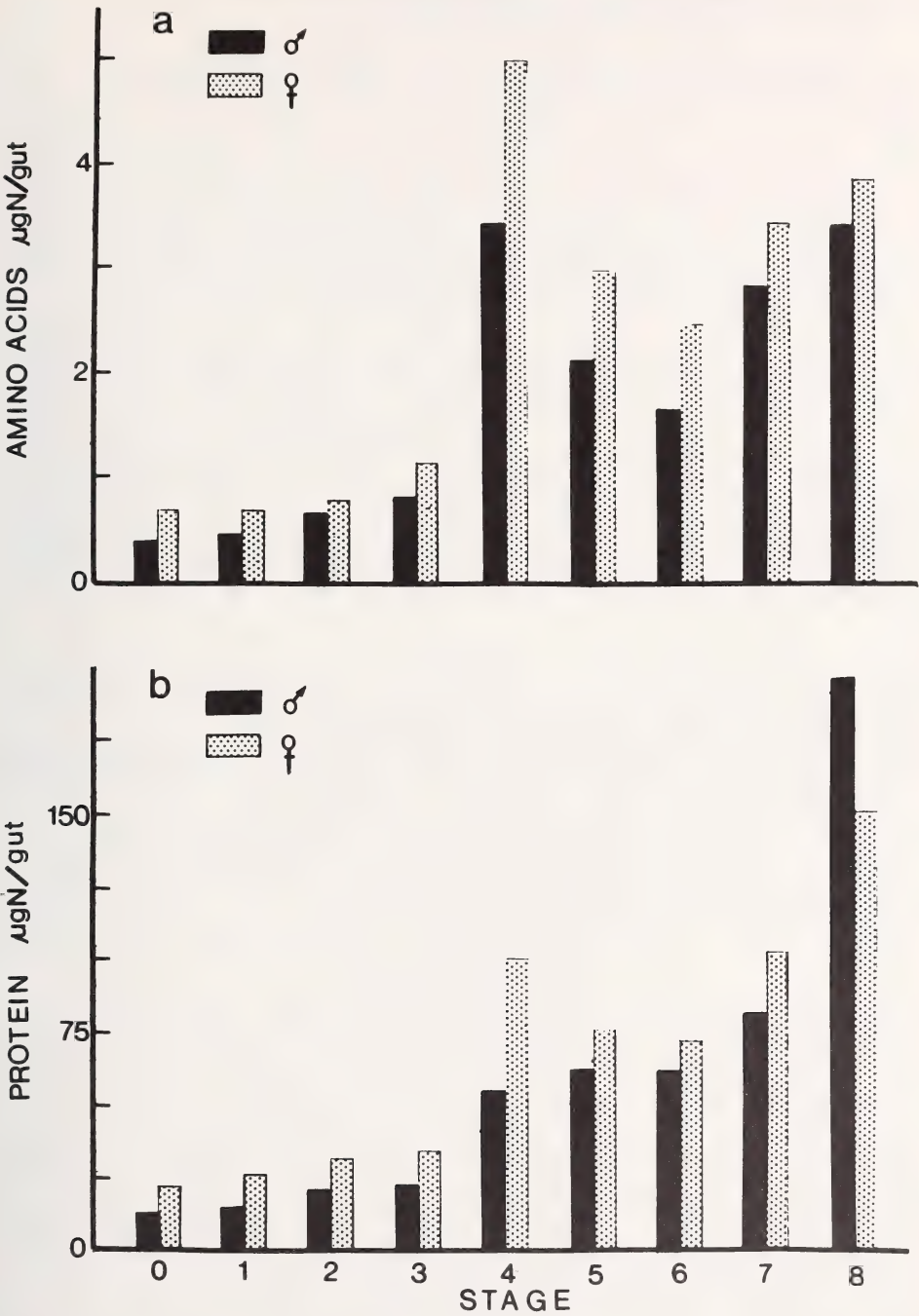


FIGURE 1. Amino acid (a) and protein (b) content of the gut of *N. sertifer* during metamorphosis.

development; instead, it increased slightly in stages 5 and 6 and sharply in stages 7 and 8 to a significantly higher level than in females.

Protein in the gut of female pupae represents approximately 11% of the total soluble protein of the body, and amino acids represent about 9% of total body content (percentages calculated from data in this report and in Fogal and Kwain 1974). Hence, even in the pupa in which high levels are found, gut protein and amino acid contents make up a relatively small proportion of the total body pool. Obviously, some protein and amino acid nitrogen accumulates in the gut in the change from larva to pupa and no doubt provides some material for adult development. In the gut of female pupae, protein accumulation is followed by a significant depletion during adult development that is not observed in males. Perhaps this difference is rooted in protein requirements for egg production.

For several species of insects yolk protein precursors are synthesized by extra-ovarian tissue, particularly fat body, released into haemolymph and taken up by growing oocytes (Engelmann 1976). In the sawfly, the fat body breaks down as egg production occurs. Protein from this and other tissues or organs, including gut, may provide necessary materials for egg production and development of other adult tissues. The gut appears to play a role in the redeployment of protein and amino acid nitrogen during the larva-pupa-adult transformation. Perhaps it is simply a reservoir function which is more evident in females because of additional protein demands for egg production. Females are certainly less wasteful of protein, as they secrete less into the gut during the formation of meconium than do males.

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**AN ATTEMPT TO PRODUCE APOSYMBIOTIC
SITOPHILUS ZEAMAI
(COLEOPTERA: CURCULIONIDAE) BY REARING AT 33°C**

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The presence of internal symbiotic microorganisms can benefit insects in a number of ways. Attempts have been made to determine the benefit of such microbiota by eliminating them so that the development and behavior of insects with and without them can be compared. Insects without symbiotes, that is, 'aposymbiotic', have been produced by various methods including high-temperature rearing as in *Pseudococcus citri* (Risso) at 37°C (Fink 1952), in *Blattella germanica* (L.) at 39°C (Brooks and Richards 1955), in *Oryzaephilus surinamensis* (L.) and *Rhizopertha dominica* (F.) at 36°C (Huger 1956), and *Sitophilus oryzae* (L.) at 35°C (Schneider 1956).

The maize weevil, *Sitophilus zeamais* Motschulsky harbors spiral and C-shaped symbiotes in a larval mycetome and in adult mesentera and ovarioles (Musgrave and Homan 1962). As yet there is no evidence of the functional significance of these symbiotes. The present work was initiated to produce an aposymbiotic strain of maize weevil by rearing at a high temperature.

Weevils were reared in an environmental chamber on soft Ontario Yorkstar wheat for twelve weeks at 33°C as compared to controls reared at 27°C. Earlier observations showed that weevils did not survive at temperatures above 33°C. At both temperatures, the relative humidity was maintained at 76% using sodium chloride solutions as described by Wexler and Hasegawa (1954). Survivors were removed and placed on fresh wheat every four weeks. Every two weeks insects were selected and larval mycetomes and adult mesentera and ovarioles were dissected out and examined for symbiotes by light and electron microscopy. Smears of each tissue in Drosophila Ringer's solution were either directly observed by phase-contrast microscopy or stained in Gram's or Giemsa's solution. Epon-embedded sections (0.5-1.0 μ m) for light microscopy were stained with 1% basic fuchsin in 95% methanol or 0.1% toluidine blue. Tissues were fixed for electron microscopy as described by Musgrave and Grinyer (1968).

Mycetomes, and mesenteral and ovarian mycetocytes of *S. zeamais* reared at 33°C were undersized with symbiotes unidentifiable with the light microscope in section or smear preparations. Numerous myelin bodies and filamentous structures, presumably remnants of symbiotes, were seen. Only in ovarian mycetocytes of a few specimens did tightly spiraled symbiotes remain. A few progeny (F₁) of adults reared at 33°C were found, when reared at 27°C, to contain reduced numbers of abnormal spiral symbiotes. Electron microscopy confirmed that the remaining spirals were degenerate with cell walls separated from the symbiotes. Some of the filamentous structures were identified as mitochondria, others as degenerate symbiotes. C-shaped symbiotes were not seen after two weeks rearing at 33°C. Both spiral and C-shaped symbiotes were identified from control weevils reared at 27°C. Attempts to maintain a culture of weevils at 27°C that was free of C-shaped symbiotes was successful, however spiral symbiotes were not entirely eliminated. The near-aposymbiotic weevils had a lower fecundity, delayed development and higher mortality. They were slower to emerge and their cuticle tanning was delayed.

These results suggest that 33°C is lethal to C-shaped symbiotes but not lethal to all spiral symbiotes. Perhaps, as in *S. oryzae* a higher temperature is needed to produce aposymbiosis in *S. zeamais* (Schneider, 1956). Degeneration of spiral symbiotes was similar to that reported in *S. zeamais* by Musgrave and Grinyer (1968). Spiral symbiotes surviving temperatures of 33°C likely multiplied to repopulate mycetocytes when insects were returned to conditions where the temperature was held constant at 27°C.

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**CONSERVATION AREAS FOR THE EASTERN POPULATION OF THE
MONARCH BUTTERFLY,
DANAUS PLEXIPPUS PLEXIPPUS,
(LEPIDOPTERA: DANAIDAE)**

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The first report of the overwintering sites of the eastern population of the monarch butterfly, *Danaus plexippus plexippus* (L.), was published in the August 1976 issue of National Geographic. Monarch butterflies migrate southward to the Neovolcanic Plateau of southern Mexico. Here they congregate on branches and trunks of various species of coniferous trees. One locus may cover a thousand trees and the various loci involve countless millions of migrant butterflies. The possibility of mass destruction of the butterflies became apparent when it was recognized that these roosting trees could easily be destroyed by fire. In fact, on at least one occasion, a fire lit under roosting trees has destroyed monarchs. Lumbering practices and hazards created by visitors intent on taking photographs also pose threats.

The importance of protecting the overwintering monarchs in the various loci throughout the Mexican site was brought to the attention of the Mexican authorities. It was felt that the need for conservation of the monarch butterfly should also be brought to the notice of the Mexican citizens. Documentary material on the northern breeding range of the monarchs was presented through the Mexican television network. The response to the televised hour-long documentary was most gratifying. Hundreds of letters were received by the President of Televisa, Miguel Aleman, requesting protection for this unique Mexican occurrence. Suggestions were made that all areas where the monarch butterflies congregate should be set aside as conservation areas.

As a result of a final meeting in my home with Dr. Ricardo Enriquez, Special Consultant to the Subsecretario Forestal y de La Fauna de Mexico, Mrs. Urquhart and I were informed that a law would be passed immediately declaring all mountains between the levels of 2500-3500 m in the Neovolcanic Plateau as wildlife sanctuaries. These areas will be patrolled by trained armed guards and a fine of \$800.00 U.S. will be imposed on anyone entering these areas without official sanction. Lumbering practices have been forbidden in the protected areas.

I gratefully acknowledge the sponsorship of research and field expeditions in past years by the National Geographic Society and the National Research Council of Canada.

(Received 24 March 1980)

Editorial Note

The devotion and perseverance of the Urquharts to the long standing question of where the monarch butterfly overwinters has resulted in a number of awards. These include one from the Televisa de Mexico for the documentary and the Franklin L. Burr Award from the Committee for Research and Exploration of the National Geographic Society, Washington, D.C. The executive and members of the Entomological Society of Ontario congratulate you.

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I. THE SOCIETY

PRESIDENT'S PRIZE — 1980

David A. Brodie, Department of Zoology, University of Western Ontario, won this year's "President's Prize" for the best student paper presented at the Annual Meeting at Spencer Hall, University of Western Ontario, London, Ontario. His paper, entitled "The Golgi Complex Beads in Insects", was judged the best of eight in the competition this year.

Mr. Brodie was born in Kingston, Ontario in 1952. He received a B.Sc. in Zoology in 1975 from the University of Toronto and a M.Sc. in Marine Biology from the University of New Brunswick at St. John in 1978. He is now working on a Ph.D. degree under the direction of Professor Michael Locke, University of Western Ontario. The objectives of his research are: 1) to determine why only arthropod beads stain with bismuth, 2) to determine the function of Golgi complex beads in intracellular transport and, 3) to describe the Golgi complex beads in vertebrates.

This is the second award for Mr. Brodie this year. He was awarded a 1980 Special University Scholarship from the University of Western Ontario.

JOINT MEETING PLANNED

The entomological societies of Ontario, Canada and America will be meeting jointly in the Royal York Hotel, Toronto, Ontario from 28 November to 2 December, 1982. Watch for future announcements and plan now to attend.

ENTOMOLOGISTS AVAILABLE

The Employment Committee of the Entomological Society of Canada has published the 1981 edition of the booklet containing the resumés of members who are looking for employment. A copy of this booklet has been sent to all present employers of entomologists in Canada, including Agriculture Canada and Environment Canada research stations, as well as the chairmen of all university biology departments. If you do not have access to this publication, a copy may be obtained from:

The Chairman
Employment Committee (Entomological Society of Canada)
Department of Environmental Biology
University of Guelph
Guelph, Ontario
N1G 2W1

AMATEUR ENTOMOLOGY IN ONTARIO

The E.S.O. was spearheaded in 1863 by a young divinity student from Toronto (Charles Bethune), and a pharmacist from London (William Saunders). The society's rooms in those early days were open to interested youngsters as well as adults, and meetings took place around tables covered with notebooks, reports, and cigar boxes full of insects. The people at these meetings were mostly amateurs. Even after 25 years the society only had two professional entomologists (Baker 1939).

Things have changed, however, and the amateur entomologist, with his cigar box full of insects and notebooks full of observations, has a hard time fitting into the society of jargon-spewing professionals that we seem to have become. This is a deplorable state because interested amateurs can not only make important contributions in their own right, but help promote public interest in entomology.

The inclusion of a session for amateurs at annual meetings, such as the very successful one at the 1980 London meetings, is an important step towards rectifying this situation. A further step we are currently taking is the initiation of a newsletter for amateurs called *The Ontario Insect Collectors' Newsletter*. Editing and preparation of the newsletter is a joint undertaking of E.S.O. and the Toronto Entomologists' Association. Hopefully, it will serve to unite Ontario amateurs and serve as a vehicle for notes on collecting, natural history, exchanges, and other material of general interest.

If you wish to be on the mailing list or submit an article, please contact Steve Marshall, Dept. of Environmental Biology, University of Guelph, Guelph, Ontario, N1G 2W1 or Allan Hanks, Toronto Entomologists' Association, 34 Seaton Drive, Toronto, Ontario, L4G 2K1.

Reference

- BAKER, A. W. 1939. A short history of the Entomological Society of Ontario. *Can. Ent.* **71**: 14-24.

II. SUBMITTED PAPERS

COMPARATIVE EFFICACY OF A HYDRAULIC BOOM AND COMPRESSED-AIR BOOM SPRAYER FOR SPRAY COVERAGE AND CONTROL OF LEAFHOPPERS AND BLIGHT IN CARROTS

R. W. FISHER¹, D. R. MENZIES¹, J. C. SUTTON²,
and A. B. STEVENSON¹

Abstract

Proc. ent. Soc. Ont. 111: 3-6 (1980)

Application of pesticide to carrots by a hydraulic spray boom (HB) with full-cone nozzles and a compressed-air boom (Conjet) with air-shear nozzles were compared at the Holland Marsh near Bradford, Ontario in 1979. Only the Conjet at 160 L/ha and 7.2 km/h gave a coverage rating below six. For control of the leafhopper vector of aster yellows disease, the Conjet applying 240 L/ha at 4.8 km/h was most effective; the Conjet at 160 L/ha and 7.2 km/h was as efficient as the HB at 360 L/ha and 4.8 km/h; and all treatments except the HB at 240 L/ha and 7.2 km/h were better than the unsprayed check. Although the incidence of leaf blight was low, there was an indication the fungicide penetrated the foliage better when applied with the Conjet than with the HB.

Introduction

Pesticide sprays are used extensively in the Bradford area marshes of Ontario to control alternaria leaf blight, *Alternaria dauci* (Kuhn) Groves and Skolko; cercospora leaf spot, *Cercospora carotae* (Pass.) Solh.; carrot rust fly, *Psila rosae* (Fab.); and the aster leafhopper, *Macrostes fascifrons* (Stål.), (Gillespie and Sutton 1979; Stevenson 1976). Extensive pesticide use on carrots and other crops has resulted in accumulation of residues of certain pesticides in the soil (Miles *et al.* 1978) and in the drainage system of the Holland marsh (Miles and Harris 1978).

Improving the efficiency of application is one means of reducing pesticide loads while maintaining adequate pest control. Toward this end, a comparison was made of the efficiencies of two low volume applicators by assessing the distribution of dye, leafhopper numbers and intensity of alternaria blight.

Materials and Methods

The sprayer fitted with a hydraulic boom (HB) and a compressed-air boom (Conjet) was used (Fisher *et al.* 1978). The HB was fitted with full cone TG-0.6 nozzles at 0.3-m spacing, and the Conjet with K-180 air nozzles + 5006 flat fan liquid nozzles at 0.5-m spacing. All the nozzles were from Spraying Systems Co., c/o John Brooks & Co. Ltd., 255 Hymus Blvd., Pointe Claire 730, P.Q., Canada. Nozzles were kept about 30 cm above the carrot foliage. The HB was operated at 1500 kPa and dispensed 360 L/ha at 4.8 km/h and 240 L/ha at 7.2 km/h; the Conjet was operated at 72.5 kPa and dispensed 240 L/ha at 4.8 km/h and 160

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L/ha at 7.2 km/h. The air pressure of 17 kPa gave a shearing velocity of about 160 m/s.

Field plots of carrot cv. Hipack were arranged in a randomized plot design with 4 replicates of 5 treatments. Carrots were sown directly in rows 43 cm apart. The block was 9.1 x 426 m and each plot comprised a 9.1 x 18.2 m "treated area" and a 9.1 x 3.1 m buffer area in which to stop, make adjustments, and start the sprayer for the next "treated area".

Application. The five treatments were: HB 4.8 km/h; HB 7.2 km/h; Conjet 4.8 km/h; Conjet 7.2 km/h; and untreated check.

To control aster leafhopper, carbaryl (Sevin 50 WP) at 3.4 kg product/ha was applied 16, 26 July, and 9 August. To control carrot leaf blights, chlorothalonil (Bravo-500) at 2.8 L product/ha was applied 1, 13, 22 August, 4 and 14 September. Because no carrot rustflies were trapped nearby, control sprays were not required for this pest. Phosphor 2283 fluorescent dye was added to the 9 August spray at 1 g/L. This dye was obtained from Sylvania Electric Products Inc., Chemical and Metallurgical Div., Towanda, Pa. 18848.

Sampling and Analyses. Leafhoppers were sampled by making 100 sweeps per plot with a 36-cm sweeping net on 26 July, 7 and 13 August. Samples were transferred to zip-lock plastic bags and stored overnight in a freezer. Numbers of aster leafhoppers per plot were recorded. Rain interfered with the 7 August count and sampling of 2 replications was delayed until 9 August. Blight was assessed in leaves of 15 plants selected randomly in a "W" shaped pattern in each plot. Three leaves were examined on each plant, one each from the lower, middle and upper canopy, to give a total of 45 leaves/plot. Blight intensity was assessed according to Horsfall and Barratt (1945). Spray coverage was assessed 13 August. Fifty leaves from a low position (2-4 cm from ground level) were picked at random in each plot and the coverage on the adaxial surface determined with a short wave u.v. lamp using a rating guide of 1-10 (Fisher *et al.* 1976). Duncan's multiple range test was used in analyses of insect, disease and spray efficiencies. Analysis of variance was also applied to the spray data.

Results

Coverage. Only the Conjet applying 160 L/ha at 7.2 km/h gave a coverage rating below six (Table I). No significant differences ($P \geq .05$) were obtained among treatments applied by HB at both speeds and the Conjet at 4.8 km/h.

TABLE I. Comparison of spray coverage and populations of aster leafhoppers in carrots sprayed by two spraying systems operating at 3 application rates and 2 speeds at the Holland Marsh, Bradford, Ontario, 1979.

Sprayer	Speed Km/h	Volume L/ha	Mean Coverage Rating*	Mean no. of leafhoppers/ 100 sweeps	
				First Count 26 July	Third Count 13 August
Hydraulic boom	4.8	360	7.2 a**	3.25 ± .6 a**	3.25 ± .62 b**
Hydraulic boom	7.2	240	6.9 a	2.25 ± 1.3 a	3.50 ± .59 bc
Conjet boom	4.8	240	6.8 a	4.5 ± 1.5 a	1.5 ± .25 a
Conjet boom	7.2	160	4.9 b	3.0 ± .4 a	3.25 ± .31 b
Unsprayed control	—	—	—	10.3 ± 3.2 b	4.75 ± .72 c

* On a scale of 1 to 10, where 1 = very poor coverage and 10 = over-sprayed.

** Values followed by the same letter do not differ significantly at $P \geq .05$.

Leafhopper control. Ten days after the first carbaryl spray (26 July) there were fewer leafhoppers in the sprayed than in the unsprayed plots, but there were no significant differences among the sprayed plots (Table I). On 13 August, four days after the third spray the Conjet at 240 L/ha at 4.8 km/h gave the greatest control and the HB with 360 L/ha at 4.8 km/h and the Conjet with 160 L/ha at 7.2 km/h each gave an intermediate level of control. The HB applying 240 L/ha at 7.2 km/h did not result in significantly fewer leafhoppers than the unsprayed control on 13 August (Table I). In the field, 12,504 plants were examined just prior to harvest for aster yellows disease and only nine showed typical symptoms.

Blight control. Blight intensity was low throughout the season (Table II). Disease was more intense in leaves sampled in September than in October. Combined values for blight intensity in lower, middle and upper leaves sampled in September indicated that blight was less severe in the variously sprayed carrots than in the unsprayed carrots. Combined values for October samples, however, indicated that only those carrots sprayed with the hydraulic boom operated at the higher volume and slower speed were significantly less diseased than the check plants.

TABLE II. Intensity of leaf blight in carrots sprayed with Bravo by two applicators operated at different driving speeds and volumes per hectare, at Bradford, Ontario, 1979.

Time of disease assessment	Applicator	Speed km/h	Litres/ha	% leaf area with symptoms at various canopy levels			
				Upper	Middle	Lower	Combined
4 Sept. 1979	Hydraulic boom	4.6	360	0.48 a*	1.94 a	5.37 ab	2.16 a
	Hydraulic boom	7.2	240	0.52 a	2.69 a	7.02 ab	2.81 a
	Conjet boom	4.8	240	0.82 a	2.18 a	4.7 a	2.31 a
	Conjet boom	7.2	160	1.10 ab	1.92 a	5.2 ab	2.43 a
	Unsprayed check			1.81 b	5.57 b	10.9 b	5.48 b
10 Oct. 1979	Hydraulic boom	4.6	360	0.59 a	1.72 ab	3.13 a	1.65 a
	Hydraulic boom	7.2	240	0.88 ab	1.94 ab	3.12 a	1.89 ab
	Conjet boom	4.6	240	1.22 b	1.22 b	3.74 a	1.93 ab
	Conjet boom	7.2	160	1.39 b	1.34 a	3.54 a	1.98 ab
	Unsprayed check			1.44 b	2.54 b	5.31 a	2.89 b

* Values followed by the same letter do not differ significantly at $P \geq .05$.

Penetration of dense foliage, as indicated by reduced blight intensity (Table II) was greatest with the Conjet compressed-air boom. In September, at the lower level of the plant, only the Conjet at the slowest speed had less disease than the check. In October none of the sprays penetrated the lower level well enough to give a lower incidence of disease than in the check. However, in the middle canopy, which would correspond in density to the lower level of the younger, more erect plants of September, the Conjet at both speeds was better than the check.

Discussion

The coverage ratings for both machines at both speeds were above six, which for crucifers, potatoes, tomatoes, and strawberries has been shown to be adequate if the recommended amount of pesticide is applied per hectare (Fisher and Warner 1974; Fisher & Hikichi 1975; Fisher *et al.* 1978; Fisher 1979).

Although coverage with the Conjet at 7.2 km/h was lower than with the other treatments, leafhoppers were controlled as effectively as with the HB sprayer at both speeds but less effectively than with the Conjet at the slower speed. Although coverage with the Conjet at 4.8 km/h was not better than that with the

HB at either speed, control of leafhoppers was significantly better. Control with the HB sprayer at the higher speed was not significantly better than in the unsprayed check. The superiority of the Conjet boom for leafhopper control may be due to the air carrier providing better droplet contact with active leafhoppers hidden among the leaves.

The insignificant amount of aster yellows in the crop despite a moderate infestation of leafhoppers probably reflects a very low incidence of the mycoplasma in the vector population. However, T. R. Davidson of Agriculture Canada Research Station, Vineland, Ont. believes a further 3-4% disease could develop in storage from infections not visible at harvest (Davidson, Pers. Comm.) and this might have justified the applications of Sevin to control the vector.

The low intensity of blight in the carrots caused no harvesting difficulties, even in the unsprayed check. The greater blight intensity recorded in September than in October was possibly associated with lack of blight development on new foliage produced after the September assessments, or may have been associated with appraisals by different workers on the two appraisal dates.

Under the conditions of this experiment, both spray booms were effective in providing good coverage and good control with the recommended amount of Bravo 500 per hectare; the Conjet was effective with as little as 160 litres per hectare (14 gal/acre) at 7.2 km/h (4.5 mph).

Acknowledgment

The authors express their appreciation to Harry W. Horlings, R.R. 2, Newmarket, Ontario, for use of a tractor and carrot field for the experiment; to D. B. Marshall and E. Barszcz of Agriculture Canada Research Station, Vineland Station, Ontario; to K. R. Fisher, Muck Research Station, OMAF Kettleby, Ontario; and Anne Morrow, Department of Environmental Biology, University of Guelph, Guelph, Ontario, for technical assistance.

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EFFECTS OF TANK-MIXED COMBINATIONS OF INSECTICIDES AND SUCKER CONTROL AGENTS ON EFFICACY AND ON THE YIELD AND QUALITY OF FLUE-CURED TOBACCO¹

H. H. CHENG

Research Station, Agriculture Canada, Delhi, Ontario. N4B 2W9 Canada.

Abstract

Proc. ent. Soc. Ont. 111: 7-12 (1980)

Tank-mixed combinations of insecticides and sucker control agents were applied on tobacco plants after topping to determine their effects on tomato hornworm, *Manduca quinquemaculata* (Haworth), green peach aphid, *Myzus persicae* (Sulzer), and tobacco suckers (auxillary buds), and on the yield and quality of flue-cured tobacco in Ontario.

Methidathion, profenofos, and oxydemeton-methyl + trichlorfon applied with Delete® or Pfizol 10® controlled the aphids, hornworms and suckers. Oxydemeton-methyl and pirimicarb applied with Delete® or Pfizol 10® controlled the aphids and suckers, but were ineffective in controlling hornworms. Cypermethrin, fenvalerate, permethrin and trichlorfon applied with Delete® or Pfizol 10® controlled the hornworms and suckers, but had no effect on aphids. The degree of aphid, hornworm and sucker control with the tank mixes was comparable to that of pirimicarb, trichlorfon and Delete® or Pfizol 10® applied sequentially, a standard treatment. All the treatments resulted in increased yields through reduced sucker growth, increased levels of reducing sugars, and decreased levels of total alkaloids. No phytotoxicity was observed with any of the tank-mixed treatments.

Introduction

The green peach aphid, *Myzus persicae* (Sulzer), and tomato hornworm, *Manduca quinquemaculata* (Haworth), are frequently serious pests of tobacco in Ontario (Cheng 1977a; Cheng and Court 1977), and these pests often occur at the time growers are applying chemicals for control of suckers (auxillary buds of tobacco plants). Most tobacco growers apply insecticides and sucker controls separately as suggested on the label or in the "Tobacco Production Recommendations" (Anonymous 1977; 1978). Several chemicals are used to control green peach aphids, tomato hornworms (Begg 1964; Bucher and Cheng 1971; Cheng 1975, 1977b) and suckers (Collins *et al.* 1970; Rosa 1980), and a tank mix of these compounds could reduce the cost of tobacco production. Cheng (1977b) showed that the registered insecticides for control of hornworms or aphids were compatible with the C₈-C₁₀ or C₁₀ fatty alcohol, sucker control agents in greenhouse tests and that these insecticides, applied with Emtrol® (C₈-C₁₀ fatty alcohols), controlled green peach aphids, tomato hornworms and suckers under field conditions. The investigations reported here were conducted in 1977 and 1978 to determine the effects of tank-mixed combinations of experimental and registered insecticides and C₁₀ fatty alcohols applied under field conditions on the efficacy of control and on the yield and quality of flue-cured tobacco.

Materials and Methods

The tests were carried out on full-grown, topped tobacco plants of Delhi 76 variety at the Research Station, Agriculture Canada, Delhi, Ontario. Normal

¹ Contribution No. 146 from the research station, Agriculture Canada, Delhi, Ontario.

cultural practices were followed, and recommended control measures were used for cutworms (chlorpyrifos at 1.12 to 2.24 kg A.I./ha on the soil surface), nematodes (Vorlex® soil fumigant at 56.2 L/ha) and weeds (pebulate at 4.48 to 5.60 kg A.I./ha incorporated into the soil).

All plots were 24.4 x 4.3 m wide, and arranged in a randomized block design with three replications of ten treatments in 1977, and three replications of twelve treatments in 1978. Each plot consisted of four rows of tobacco with 40 plants in each row; the outside rows in each plot were guard rows.

Insecticides tested were cypermethrin, fenvalerate, methidathion, oxydemeton-methyl, permethrin, pirimicarb, profenofos, and trichlorfon. The sucker control agents were Delete® in 1977 and Pfizol 10® in 1978, both of which contained C₁₀ fatty acids as active ingredients. Each of the insecticides was mixed in the same tank with the sucker control agent just before application. Sprays were applied with a power sprayer equipped with three nozzles per row (TG3, TG5, and TG3) that delivered 450 L/ha at 5.6 km/h and at a pressure of 100 kPa. All treatments, except the untreated check, were applied evenly over the tops of the plants in each plot one day after topping. This was on 27 July in 1977 and 31 July in 1978. In addition, separate applications were included in the tests as a standard treatment. For this treatment, pirimicarb was used for aphid control, trichlorfon for hornworm control and Delete® or Pfizol 10® for sucker control. Pirimicarb was applied first, on 25 July in 1977 and 29 July in 1978, followed by Delete® or Pfizol 10® two days later, and finally trichlorfon after one more day.

The effectiveness of the treatments was evaluated by methods previously described (Cheng 1977b). Five harvests were taken from each plot and cured in the conventional manner (Walker and Vickery 1969). Cured tobacco leaves were analyzed to determine the effect of tank-mixed combinations of insecticides and sucker control agents on the quality of the tobacco. The agronomic parameters measured were yield, grade index (Anonymous 1965) and monetary returns per hectare. The chemical parameters measured were reducing sugars (Harvey *et al.* 1969) and total alkaloids (Griffith 1957).

The numbers of aphids were transformed to $\log_{10}(X + 1)$ and hornworms to $\sqrt{X + 0.5}$ before analysis of variance. An analysis of variance was used on all data and Duncan's multiple range test was used to test for significant differences between treatment means. Mean values of aphid and hornworm counts were converted to original units for presentation in Table I.

Results and Discussion

Aphid and Hornworm Control. In 1977, methidathion, oxydemeton-methyl, oxydemeton-methyl + trichlorfon, or pirimicarb applied as a tank mix with Delete® at 16.84 L/ha and the standard treatment significantly reduced the number of green peach aphids for at least two weeks when compared with the untreated check, or those treated with other tank-mixed combinations (Table I). The pirimicarb-Delete® combination was as effective as the standard treatment. Cypermethrin, fenvalerate, permethrin, and trichlorfon applied with Delete® were ineffective in controlling aphids in this test, and no significant differences among these treatments were observed. Because of low populations in 1977 (Table I), no conclusions could be made on the relative effectiveness of these insecticides for tomato hornworm.

In 1978, oxydemeton-methyl + trichlorfon or profenofos applied with Pfizol 10®, and the standard treatment provided good control of the aphids and

TABLE I. Comparative effectiveness of tank-mixed combinations of insecticides and sucker control agents against green peach aphid, tomato hornworm and suckers on flue-cured tobacco in Ontario.

Treatment		No. of living aphids/ leaf			No. of living hornworm/plot		No. of suckers per plant ^a
Material	Rate (kg AI/ha)	Pre-spray ^b	Days post spray ^a	Pre-spray	3 days post spray		
1977 experiment: mixed with Delete® at 16.84 liters/ha							
Cypermethrin	0.05	147	119bc	151b	1.0 ^b	0.0 ^b	4.7a
Fenvalerate	0.05	217	197bc	214bc	0.4	0.0	2.6a
Methidathion	0.50	140	5a	6a	0.3	0.0	2.6a
Oxydemeton-methyl	0.28	285	1a	2a	0.7	0.0	3.4a
Oxydemeton-methyl + trichlorfon	0.28 + 1.12	160	2a	6a	0.3	0.0	2.9a
Permethrin	0.05	132	94b	129b	1.4	0.0	3.7a
Pirimicarb	0.28	154	2a	5a	0.7	0.0	4.2a
Trichlorfon	1.12	160	161bc	198bc	1.0	0.0	3.1a
Standard treatment ^c	—	181	0a	4a	1.2	0.0	2.4a
Check (hand-suckered)	—	283	381c	488c	1.7	1.3	16.6b
1978 experiment: mixed with Pfizol 10® at 16.84 liters/ha							
Cypermethrin	0.05	114	91bc	227cd	1.0ab ^a	0.0a ^a	3.1a
Fenvalerate	0.15	103	77bc	118bc	1.3ab	0.0a	2.2a
	0.05	91	73bc	146bcd	0.7a	0.0a	2.9a
	0.15	73	49b	75bc	1.6ab	0.0a	3.2a
Oxydemeton-methyl	0.28	156	0a	1a	2.2ab	1.0ab	3.2a
Oxydemeton-methyl + trichlorfon	0.28 + 1.12	131	0a	2a	2.0ab	0.0a	2.8a
Permethrin	0.05	78	62bc	155bcd	3.0b	0.0a	2.6a
Pirimicarb	0.28	82	0a	3a	1.6ab	0.6ab	3.0a
Profenofos	0.50	97	20ab	44ab	0.7a	0.0a	3.3a
Trichlorfon	1.12	144	102bc	238d	1.3ab	0.0a	2.4a
Standard treatment ^c	—	126	2a	7a	2.7b	0.0a	4.3a
Check (hand-suckered)	—	75	265c	526d	3.3b	2.6b	15.7b

^aMeans followed by the same letter are not significantly different at 5% level as determined by Duncan's multiple range test.
^bF test not significant for these data.
^cPirimicarb, trichlorfon and Delete® or Pfizol 10® were applied sequentially.

hornworms, however, the aphids were more numerous after spraying in the profenofos-treated plots than in those treated with oxydemeton-methyl + trichlorfon and the standard treatment (Table I). A tank mixture of oxydemeton-methyl or pirimicarb with Pfizol 10[®] significantly reduced the number of aphids per leaf but did not control hornworms. There were no significant differences in effectiveness among the pirimicarb, oxydemeton-methyl, oxydemeton-methyl + trichlorfon or the standard treatment against aphids. Cypermethrin, fenvalerate, permethrin, and trichlorfon applied with Pfizol 10[®] significantly reduced the number of hornworms when compared with untreated check plots, but did not control aphids. The trichlorfon-Pfizol 10[®] combination was as effective as the standard treatment in controlling hornworms. The higher rates of cypermethrin or fenvalerate did not protect the tobacco plants from aphids although the population was reduced. The results suggest that the inclusion of sucker control agents did not affect insecticidal action.

Sucker Control. All combinations of insecticide + Delete[®] or Pfizol 10[®] tested in 1977 and 1978 and the standard treatment were similar in effectiveness and

TABLE II. Effects of tank-mixed combinations of insecticides and sucker control agents on agronomic and chemical parameters of flue-cured tobacco in Ontario.

Treatment	Rate (kg AI/ha)	Yield ^a (kg/ha)	Grade ^b index (\$/kg)	Return ^a index (\$/ha)	Reducing ^b sugars (%)	Total ^a alkaloids (%)
1977 experiment: mixed with Delete [®] at 16.84 liters/ha						
Cypermethrin	0.05	3156.2a	2.29	7242.5ab	16.32	3.03ab
Fenvalerate	0.05	3127.0a	2.32	7265.0ab	17.78	3.08ab
Methidathion	0.50	3096.8a	2.33	7226.7ab	19.63	2.85bc
Oxydemeton-methyl	0.28	3088.6a	2.29	7091.7bc	18.01	3.22ab
Oxydemeton-methyl + Trichlorfon	0.28 + 1.12	3169.6a	2.32	7368.7a	17.94	3.24ab
Permethrin	0.05	3158.4a	2.32	7326.5a	18.71	3.14ab
Pirimicarb	0.28	3141.6a	2.33	7324.3a	19.74	2.79c
Trichlorfon	1.12	3047.5ab	2.28	6941.6cd	16.91	3.35ab
Standard treatment ^c	—	3076.8a	2.31	7100.4bc	17.95	3.04ab
Check (hand-suckered)	—	2932.5b	2.30	6763.5d	16.26	3.48a
1978 experiment: mixed with Pfizol 10 [®] at 16.84 liters/ha						
Cypermethrin	0.05	3363.4ab	2.54	8545.1a	20.65	2.37ab
	0.15	3300.1abc	2.52	8310.6b	21.27	2.32ab
Fenvalerate	0.05	3363.9ab	2.55	8587.0a	22.19	2.16ab
	0.15	3324.0abc	2.46	8167.1bc	22.32	1.98b
Oxydemeton-methyl	0.28	3308.6abc	2.51	8302.5b	19.93	2.36ab
Oxydemeton-methyl + Trichlorfon	0.28 + 1.12	3223.5bcd	2.53	8163.2bc	20.66	2.09ab
Permethrin	0.05	3240.9abcd	2.50	8098.7cd	21.56	2.29ab
Pirimicarb	0.28	3195.1bcd	2.54	8111.7cd	21.36	2.53ab
Profenofos	0.50	3154.2cd	2.52	7951.8d	18.78	2.25ab
Trichlorfon	1.12	3397.0a	2.45	8308.4b	19.90	2.45ab
Standard treatment ^c	—	3296.0abc	2.48	8170.3bc	20.63	2.47ab
Check (hand-suckered)	—	3057.2d	2.44	7459.2e	18.77	2.60a

^a Means followed by the same letter are not significantly different at 5% level as determined by Duncan's multiple range test.

^b F test not significant for these data.

^c Pirimicarb, trichlorfon and Delete[®] or Pfizol 10[®] were applied sequentially.

caused a significant reduction in the number of suckers per plant as compared with the untreated check (Table I). No phytotoxicity was observed with any of the mixtures and it appeared that the insecticides tested could be applied at the same time without adverse effects on the tobacco. This would reduce production costs by decreasing the number of spray applications.

Agronomic and Chemical Data. The effects of the tank-mixed combinations of insecticides and Delete® or Pfizol 10® on certain agronomic and chemical characteristics in each year are shown in Table II). The standard treatment and all the combinations except trichlorfon-Delete® in 1977, significantly increased yield and return index both years as compared to the untreated check. Treatment had no effect on the grade index.

Chemical analysis of cured tobacco leaves from the two years indicated that all the mixtures and the standard treatment reduced the total alkaloids and increased reducing sugars in tobacco when compared with the untreated check (Table II). The tendency towards lower total alkaloids and higher reducing sugars in tobacco was always observed when the tobacco plants were treated with only sucker control chemicals, C₈-C₁₀ or C₁₀ fatty alcohols (Rosa 1980). Therefore, these chemical data suggest that the metabolism of the plants was unaffected by tank mixing the chemicals.

In general, the results suggest that tank mixtures of one of these insecticides and a sucker control agent could be sprayed on tobacco without altering the effectiveness of either material. The application of two or more chemicals at one time would reduce labor and equipment requirements in late July and August, a peak period for use of labor and equipment on tobacco farms.

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EVALUATION OF INSECTICIDES FOR THE CONTROL OF THE HAIRY CHINCH BUG (HEMIPTERA: LYGAEIDAE) IN ONTARIO LAWNS

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Abstract

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A number of insecticides were evaluated over a 5-year period for control of *Blissus leucopterus hirtus* Montandon. Chlorpyrifos and CGA 12223 at 1-2 kg AI/ha and diazinon at 2-4 kg AI/ha provided the most consistent control. Treatments early in the season when most of the hairy chinch bugs were in the 3rd instar gave better control than those applied later when bugs were mature.

Introduction

The hairy chinch bug, *Blissus leucopterus hirtus* Montandon, has been reported from Ontario (Caesar 1911; Caesar and Ross 1922), New York (Maxwell and MacLeod 1936), Connecticut (Walden 1936), New Jersey (Hamilton 1936) and Ohio (Polivka 1965) as a serious but periodic pest of turfgrass. In recent years, it has caused considerable damage to lawns, sod farms, and golf courses in southern Ontario (Goble 1971, 1972; McEwen 1973). Current recommendations for control in Ontario include organophosphate and carbamate insecticides commonly used for control of other turfgrass insects (Ont. Min. of Agric. & Food. 1979).

Liu and McEwen (1979) developed a sequential sampling plan for detecting populations likely to cause damage. They suggested that the optimum period for insecticide applications was the time when peak numbers of 3rd-instars occurred. This period can be predicted by a temperature accumulation in the thatch of 750-950 day-degrees above a 7°C threshold. A single, timed insecticide application should be sufficient to control a univoltine insect such as the hairy chinch bug (Liu and McEwen 1979). We examined a number of insecticides for effectiveness against the hairy chinch bug and those materials which provided control with a single application were identified.

Materials and Methods

A series of efficacy experiments was performed from 1973 to 1977 on homeowner lawns consisting primarily of fescue/bluegrass mixtures of turfgrass. Treatment plots were 3.1 x 6.2 m in 1973 and 1974, 4.6 x 4.6 m in 1975 and 1976, and 3.2 x 3.2 m separated by 1 m untreated borders in 1977. Liquid formulations were applied in water with a knapsack sprayer at the rate of 600 liters/ha in 1973 and 1974, 900 liters/ha in 1975 and 1976, and 1,000 liters/ha in 1977. Granular materials were applied using a drop-type fertilizer spreader that was calibrated to deliver the desired rate of each material. In 1977, preweighed samples of granular materials were applied to each plot using a metal can with appropriate openings. Four replications of each treatment were applied in a completely randomized design for each experiment. Following treatment, samples were taken from each plot using a metal square or cylinder that was forced into the turf. The containers were flooded for 15 minutes and the number of living and dead chinch bugs that floated to the surface was determined.

Because data were extremely variable in 1973-74, counts were taken in each lawn to determine the general population density prior to treatment in 1975-77.

These pretreatment counts were not taken to analyze the efficacy of the treatments. Rather, posttreatment estimates of the proportion of live and dead hairy chinch bugs in each replicate were used.

The following insecticides were included in the tests: Aspon (0,0,0',0'-tetra-n-propyl dithiopyrophosphate), bendiocarb, carbaryl, carbofuran, CGA 12223 (0-[5-chloro-1-[methylethyl]-1H-1,2,4-triazol-3-yl] 0,0-diethyl phosphorothioate), chlordane, chlorpyrifos, diazinon, methidathion, permethrin, and pirimiphos-ethyl.

Eighteen treatments (Table I) were applied to two heavily infested lawns on 9 Aug., 1973. Estimates of treatment effectiveness were made on 13 and 14 Aug., by taking three samples from each plot. Samples were obtained by flooding one 930 cm² metal square and two 645 cm² squares within each plot. Turf within the flooded squares was thoroughly agitated and the water allowed to stand for 15 min so that living and dead hairy chinch bugs would float to the surface.

TABLE I. Mortality of hairy chinch bugs in turfgrass treated with various insecticides at Guelph, Ontario, Aug. 9, 1973.

Treatment	Formulation	Rate (kg AI/ha)	4-5 Days Posttreatment	
			Mean no. bugs recovered ^a	Mean % dead ^b
Chlorpyrifos	1.35G	4.5	14.3	83.1 a
Chlorpyrifos	1.35G	2.3	16.2	86.5 a
Chlorpyrifos	2.4E	4.5	14.4	83.2 a
Methidathion	40 EC	4.5	11.5	80.9 a
Carbaryl + Chlordane	8.3G + 8.3G	11.2 + 11.2	10.3	
Carbaryl + Chlordane	8.3G + 8.3G	5.6 + 5.6	10.6	80.5 a
Carbaryl	80 S	9.0	7.1	69.4 a
Aspon	5 G	6.7	6.1	79.4 a
Diazinon	4.5G	5.6	11.4	79.2 a
Carbofuran	4.8F	4.5	6.0	78.5 a
Diazinon	2 G	5.6	11.2	78.1 a
Pirimiphos-ethyl	1.9G	2.3	10.0	75.7 a
Pirimiphos-ethyl	1.9G	1.1	19.1	73.5 a
Diazinon	50 EC	4.5	9.3	65.5 a
Methidathion	14 G	4.5	5.7	71.9 a
Aspon	6 E	6.7	4.0	69.6 a
Chlordane	40 EC	5.6	11.6	65.6 a
Check			9.4	43.0 b
				39.2 b

^a Per 750 cm².

^b Mean of 4 replications; data transformed by arc-sine transformation before analysis; means followed by the same letter are not significantly different at $P = 0.05$, Duncan's multiple range test.

Seventeen treatments (Table II) were applied to two lawns on 9 Aug., 1974, and estimates of treatment effectiveness obtained on 12 and 13 Aug. Samples were taken in the same manner as that used in 1973.

Twenty-two treatments were applied (Table III) to four heavily infested lawns on 5 Aug., 1975. Prior to treatment, ten samples were taken at random from each lawn using a round, metal sleeve, 185 cm² in area. Lawns were irrigated with 0.7 cm of water immediately following insecticide application. Efficacy of these

TABLE II. Mortality of hairy chinch bugs in turfgrass treated with various insecticides at Guelph, Ontario, Aug. 9, 1974.

Treatment	Formulation	Rate (kg AI/ha)	3 Days Posttreatment	
			Mean no. bugs recovered ^a	Mean % dead ^b
Chlorpyrifos	1.35G ^c	2.3	18.2	73.5 a
Chlorpyrifos	1.35G ^d	2.3	20.0	61.7 ab
Carbofuran	6.7F	4.5	16.0	61.3 ab
Carbofuran	6.7F	2.3	9.8	60.4 ab
Carbaryl	50 WP	9.0	9.6	61.3 ab
Carbaryl	50 WP	4.5	6.5	60.0 ab
Diazinon + N	3.6G	5.6	15.1	60.0 ab
Diazinon	4.5 G ^d	5.6	40.1	49.4 abc
Diazinon	4.5 G ^c	5.6	14.9	41.1 bcd
Chlorpyrifos	4 E	2.3	17.8	47.9 abc
Chlorpyrifos	4 E	1.1	24.8	31.3 bcd
Methidathion	40 EC	2.3	22.3	36.6 bcd
Methidathion	40 EC	1.1	14.2	47.8 abc
Carbaryl + Chlordane	2.75G + 2.75G	5.6 + 5.6	17.6	44.4 abcd
Diazinon	50 EC	4.5	23.8	36.0 bcd
Check			45.3	14.0 d
Check			20.4	19.2 cd

^a Per 750 cm²^b Mean of 4 replications; data transformed by arc-sine transformation before analysis; means followed by the same letter are not significantly different at $P = 0.05$, Duncan's multiple range test.^c Bentonite clay carrier.^d Corn cob carrier.

treatments was assessed on 7 and 12 Aug. by taking four samples from each plot using the metal sleeve (185 cm²).

In 1976, treatments were timed to coincide with the peak population of 3rd-instars as well as with adults. Insecticides were applied on 9 July to two lawns infested primarily with 3rd-instars and on 9 Aug. to two different lawns infested with mature hairy chinch bugs. Both applications consisted of the same 12 treatments (Table IV). Ten samples were taken at random from each lawn before treatment to determine the level of infestation. All treated areas were irrigated (0.7 cm) immediately following application and 2.5 cm of rain were recorded in the area over the three days following the July treatment. Four samples of 185 cm² were taken from each plot 2-3 days following application using a metal sleeve.

Smaller plots of 3.2 x 3.2 m were used in 1977. A one m strip between plots was left untreated to reduce movement of the hairy chinch bugs between plots. Fifteen treatments (Table V) were applied to four lawns on 19 July. As in 1976, a few pretreatment samples were taken at random from each lawn and all plots received irrigation immediately following application. Counts of hairy chinch bugs were taken 2-3 days and 7 days posttreatment, again taking four samples of 185 cm².

Results and Discussion

All treatments evaluated in 1973, except chlordane, provided significant mortality of the hairy chinch bug compared to the untreated check (Table I). Movement between plots was suspected and would account for the higher-than-

TABLE III. Mortality of hairy chinch bugs in turfgrass treated with various insecticides at Guelph, Ontario, Aug. 5, 1975.

Treatment	Formulation	Rate (kg AI/ha)	2 Days Posttreatment		7 Days Posttreatment	
			Mean no. bugs recovered ^a	Mean % dead ^b	Mean no. bugs recovered ^a	Mean % dead ^b
CGA 12223	10G	4.0	16.7	64.7 abcd	11.4	77.9 ab
CGA 12223	10G	2.0	27.6	73.0 ab	29.2	81.7 ab
CGA 12223	10G	1.0	19.0	74.3 a	19.9	76.8 ab
CGA 12223	10G	0.5	37.6	57.8 abcdef	28.9	72.6 ab
CGA 12223	500E	4.0	34.4	72.8 ab	29.0	79.5 ab
CGA 12223	500E	2.0	21.1	77.4 a	30.1	66.9 abc
CGA 12223	500E	1.0	16.7	58.8 abcde	13.3	68.3 abc
CGA 12223	500E	0.5	26.6	51.9 bcdefg	17.4	65.6 abcd
Diazinon	5G	4.0	46.9	48.8 cdefg	41.1	64.5 abcd
Diazinon	5G	2.0	45.1	61.8 abcd	46.3	75.0 ab
Diazinon	5G	1.0	16.9	64.1 abcd	9.9	72.2 ab
Diazinon	5G	0.5	74.4	33.1	46.6	59.4 abcde
Diazinon	50EC	4.0	41.5	50.1 cdefg	31.1	70.5 abc
Diazinon	50EC	2.0	33.3	45.7 defg	25.3	71.7 abc
Diazinon	50EC	1.0	26.9	46.6 defg	29.2	56.9 bcde
Diazinon	50EC	0.5	25.3	47.1 cdefg	66.4	39.1 ^e
Diazinon	4.5G	5.6	41.3	46.9 cdefg	25.1	67.2 abc
Chlorpyrifos	1.35G	1.7	49.1	51.8 bcdefg	39.7	75.1 ab
Carbaryl +	2.75G +	5.6 +				
Chlordane	2.75G	5.6	17.9	69.4 abc	19.8	82.2 a
Chlorpyrifos	4E	2.3	44.0	50.9 bcdefg	38.4	70.1 abc
Chlorpyrifos	4E	1.1	13.7	58.5 abcdef	12.4	79.8 ab
Carbaryl	85WP	9.0	24.1	59.1 abcde	15.9	67.8 abc
Carbaryl	85WP	4.5	17.1	50.1 cdefg	15.0	66.2 abc
Check			33.2	38.7 efg	51.5	46.9 cde
Check			23.5	36.1 fg	42.2	42.2 de

^a Per 185 cm².

^b Mean of 4 replications; data transformed by arc-sine transformation before analysis; means in the same column followed by the same letter are not significantly different at $P = 0.05$, Duncan's multiple range test.

TABLE IV. Mortality of hairy chlnch bugs in turfgrass treated with various insecticides on July 9 or on Aug. 9, 1976 at Guelph, Ontario.

Treatment	Formu- lation	Rate (kg AI/ha)	2 Days Posttreatment, July		3 Days Posttreatment, August	
			Mean no. bugs recovered ^a	Mean % dead ^b	Mean no. bugs recovered ^a	Mean % dead ^b
CGA 12223	500E	4.0	10.3	78.8 a	1.8	49.4 ab
CGA 12223	500E	2.0	2.9	71.5 a	2.0	63.3 ab
CGA 12223	10G	4.0	3.2	65.7 ab	—	—
CGA 12223	10G	2.0	8.9	78.0 a	—	—
Chlorpyrifos	4E	2.0	2.1	70.3 a	1.5	76.7 a
Diazinon	50EC	4.0	6.2	76.2 a	0.4	58.7 ab
Diazinon	50EC	2.0	7.6	64.0 ab	1.1	66.1 ab
Diazinon	5G	4.0	7.4	65.5 ab	2.6	72.7 a
Diazinon	5G	2.0	2.1	37.9 bc	6.6	63.3 ab
Carbaryl	50WP	8.0	12.9	68.9 a	2.2	39.3 ab
Chlorpyrifos	1.34G	1.5	5.8	57.0 abc	—	—
Check			7.1	32.5 c	5.8	28.3 b
Check			5.1	33.8 c	9.4	24.3 b

^a Per 185 cm².

^b Mean of 4 replications; data transformed by arc-sine transformation before analysis; means in the same column followed by the same letter are not significantly different at $P = 0.05$, Duncan's multiple range test.

TABLE V. Mortality of hairy chinch bugs in turfgrass treated with various insecticides at Guelph, Ontario, July 19, 1977.

Treatment	Formulation	Rate (kg AI/ha)	3-4 Days Posttreatment		7 Days Posttreatment	
			Mean no. bugs recovered ^a	Mean % dead ^b	Mean no. bugs recovered ^a	Mean % dead ^b
<i>Liquid formulations</i>						
CGA 12223	500E	2.0	16.8	69.7 a	10.8	85.1 a
CGA 12223	500E	1.0	29.3	56.4 ab	14.7	78.6 a
Diazinon	50EC	4.0	8.8	62.3 ab	3.8	76.0 a
Diazinon	50EC	2.0	17.8	60.3 ab	13.5	72.5 a
Carbaryl	50WP	4.0	33.9	38.3 cd	32.7	34.5 b
Carbaryl	50WP	2.0	56.5	24.2 d	106.7	22.2 b
Permethrin	50EC	0.07	46.7	25.2 d	34.2	23.8 b
Bendiocarb	76WP	1.5	16.5	45.4 bc	15.7	35.3 b
Bendiocarb	76WP	1.0	66.1	21.7 d	64.2	20.8 b
Bendiocarb	76WP	0.5	33.3	22.4 d	41.3	25.5 b
Check			49.0	20.1 d	55.9	19.6 b
Check			58.8	21.5 d	63.0	20.6 b
<i>Granular formulations</i>						
CGA 12223	1G	2.0	52.2	77.5 ab	39.3	73.0 a
CGA 12223	1G	1.0	18.9	58.6 bcd	30.3	59.5 ab
Diazinon	5G	4.0	4.8	66.4 abc	5.2	62.2 ab
Diazinon	5G	2.0	30.6	40.7 defg	19.0	48.2 abc
Chlorpyrifos	1.35G	1.5	19.8	78.5 a	30.3	72.1 a
Chlorpyrifos	1.35G	0.75	21.6	58.0 cd	25.1	72.2 a
Chlorpyrifos + N	1.35G	1.5	57.7	54.9 cde	42.3	75.1 a
Chlorpyrifos + N	1.35G	0.75	56.6	48.1 cdef	56.4	57.1 ab
Diazinon	4.5G	9.9	34.8	36.4 efg	20.6	35.1 bcd
Diazinon	4.5G	5.6	49.0	33.2 fg	47.0	49.9 ab
Check			12.3	26.9 g	27.5	21.5 cd
Check			68.2	23.1 g	73.0	20.4 d

^a Per 185 cm².

^b Mean of 4 replications; data transformed by arc-sine transformation before analysis; means in the same column followed by the same letter are not significantly different at $P = 0.05$, Duncan's multiple range test.

expected mortality in the untreated areas. Similar results were obtained with equal rates of granular and liquid formulations.

In 1974, carbofuran and carbaryl provided effective control (Table II) as did granular formulations of chlorpyrifos and diazinon. Although populations were higher than in 1973, the variability in the numbers recovered was greater.

Considerable variability existed in the samples obtained from treated plots in 1975, but the populations were higher than in previous years. Pretreatment samples averaged 98.4, 84.9, 162.6, and 169.3 adults and nymphs/185 cm² on the four lawns examined. Granular formulations of diazinon and both granular and liquid formulations of CGA 12223 proved most effective (Table III). Carbaryl, when combined with chlordane and applied at 5.6 kg AI/ha, provided better control than carbaryl alone at 4.5 or 9.0 kg AI/ha. The high mortality in the check plots was again felt to be influenced by hairy chinch bugs leaving plots treated at low rates and entering the check plots. Because movement between plots was difficult to assess, and because the time required to adequately sample each plot before and after treatment was excessive, mortality estimates based on the proportion of live and dead bugs following treatment continued to be relied upon. The proportion of dead individuals recovered was consistent within each treatment so that a smaller number of samples was adequate for comparison with the untreated check plots.

In the 1976 tests (Table IV), the population was lower than in 1975. Treatments were applied in July after ca. 850 day-degrees were accumulated using air temperatures above 7°C. At this time, pretreatment samples averaged 6.6 and 4.5 chinch bugs/185 cm² on each lawn and 62% of the individuals recovered were 3rd-instars. All materials were effective except chlorpyrifos at 1.5 kg AI/ha and diazinon at 2 kg AI/ha. In August, population levels were again low with an average of 3.6 and 8.8 chinch bugs/185 cm² on each lawn and 93% of the bugs recovered were 5th-instars or adults. Results indicated that only the granular formulation of diazinon at 4 kg AI/ha and chlorpyrifos EC at 2 kg AI/ha were effective. Numbers recovered from plots on which CGA 12223 10G and chlorpyrifos 1.34G were applied were insufficient to assess their efficacy. Migration from infested sites was significant in August (Liu and McEwen 1979) and this may have caused an increased movement between treatments and out of the test area altogether.

Treatments were applied immediately following the peak occurrence of 3rd-instars in 1977. Pretreatment samples from the four lawns examined indicated an average population density of 33.8, 30.6, 91.6, and 25.9 chinch bugs/185 cm². The chinch bugs recovered were primarily (48.8%) in the 3rd and 4th instars. Liquid formulations of diazinon and CGA 12223 provided excellent control (> 72% transformed mortality) as did the granular chlorpyrifos formulations of these two insecticides (> 62%) and a granular chlorpyrifos formulation (> 72%) (Table V). Check mortality was less than in previous years and variability among replicates was less. This may reflect the influence of untreated strips in reducing movement between plots.

Results obtained over the 5-year period of this study indicate that diazinon at 2-4 kg AI/ha and both chlorpyrifos and CGA 12223 at 1-2 kg AI/ha provided the most consistent control. Carbaryl, Aspon, and methidathion were effective at higher rates while chlordane was ineffective. This confirms other findings (Streu 1973a) that the hairy chinch bug is not susceptible to chlordane. Streu (1973b) also indicated that increased damage from the hairy chinch bug in recent years

was due to destruction of predators and tolerance to the repeated use of residual insecticides.

Timing of the application may be the most important factor in preventing damage by the hairy chinch bug (Johnson 1941). Liu and McEwen (1979) suggested that treatment should be timed to coincide with peak numbers of 3rd-instars. By this time damage has not yet developed, all eggs have hatched, and adults are not present to migrate to new areas. Field observations during the present study support this view.

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HAIRPENCILS ON MALES OF THE ORIENTAL FRUIT MOTH, *GRAPHOLITHA MOLESTA* (BUSCK) (LEPIDOPTERA: TORTRICIDAE)

by

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Abstract

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Each of the paired, caudal hairpencils on males of the Oriental fruit moth, *Grapholitha molesta* (Busck), consists of a tuft of ca. 93 hollow scales with honeycombed, porous walls. The lumen of each scale is continuous with an underlying reservoir within a fibrous space which in turn is bounded by microvilli of an enveloping trichogen cell. The gross morphology, histology, and fine structure of the modified scales of the hairpencils and their underlying cells are typical of structures designed to continually secrete, store and disperse volatile material.

Introduction

Males of the Oriental fruit moth, *Grapholitha molesta* (Busck), possess a pair of posterior, abdominal hairpencils, "scent pencils", which are briefly displayed several times within a range of from 1 to 2 cm of the female, just prior to copulation (George 1965; Baker and Cardé 1979). The males of *G. molesta*, like those of many other moths, appear to direct a volatile pheromone towards calling females. A receptive female responds by contact with the male which usually results in copulation (Baker and Cardé 1979). Although the structure and histology of hairpencils and their associated gland cells have been described for several species of moths, little is known of the structure of those of the Tortricidae (Grant 1978).

The present study of *G. molesta* males was undertaken to determine; 1), the exact location and morphology of the modified scales that comprise the hairpencils, and 2), the histology and fine structure of both the scales and the cells underlying each hairpencil.

Materials and Methods

Specimens of *G. molesta* were obtained from a colony reared on immature apples at the Agriculture Canada Research Station, Vineland, Ontario. Males were studied one to three days after eclosion.

Scanning Electron Microscopy (SEM). The location and external surfaces of hairpencils of males were determined by dipping compressed abdomens in 70% alcohol. They were dried while the hairpencils were exposed. Specimens were carbon and gold-palladium coated and photographed with a Cambridge Mark II scanning electron microscope.

Light Microscopy (LM). Severed abdomens were fixed in Carnoy's fluid for two hours, rinsed in two changes of distilled water for 30 minutes, progressively dehydrated for one hour in each of 50%, 70%, 95% and absolute alcohol, 50:50

absolute alcohol-terpineol, cleared in terpineol and finally embedded following two changes of molten paraffin. Sections of 1-3 μm , were stained with oil red "O" and alum haematoxylin and finally mounted in glycerin jelly.

Transmission Electron Microscopy (TEM). A freshly removed abdomen was placed for two hours in a chilled fixative consisting of 6% glutaraldehyde solution buffered at pH 7.2 with 0.1 M cacodylate buffer, containing 2% sucrose and 0.01 M calcium chloride. After two, 10-minute washings with 10% sucrose in 0.1 M cacodylate at pH 7.2, the tissues were placed for three hours at 4°C in 1% osmium tetroxide (OsO_4) in 0.1 M cacodylate, pH 7.2 and 4% sucrose. This was followed by two, 10-minute rinses in distilled water, and three hours in 3% uranyl acetate, with the excess of the latter removed by rinsing with distilled water. Dehydration was achieved in a graded ethanol series to propylene oxide before embedding in Araldite. Sections were cut with a Reichert OMU3 microtome and photographed with an E.M. Philips 201.

Results

The two hairpencils on each male of the Oriental fruit moth are located in caudal pouches on either side of the abdomen between segments eight and nine and consist of 93 ± 2.5 s.d. organules (Figs. 1A and 5B). The term organule was defined by Lawrence (1966) in describing hairs and bristles of the milkweed bug. Here it refers to an individual scale of the hairpencil together with the underlying epidermal cells from which it was formed (Fig. 2). The scales are arranged in a brush-like tuft, the hairpencil, and at rest are covered laterally by the eighth abdominal tergite and supported both medially and ventrally by the upper surface of the retracted ninth tergite (Figs. 1A and 3A).

The base of each hairpencil rests in a pouch formed by an invagination of the integument which extends about one eighth (0.1 mm) of the length of the longest (0.85 mm) scale in the brush (Figs. 1A and B, and 3A and B). The dorsal scales of each hairpencil are the longest and there is a gradual diminution in length toward the ventral area (Fig. 1A). A sclerite (Fig. 1A "E") extends from the inner base of each of the hairpencils to the outer edge of the eighth sternite. Ventral movement of the eighth sternite thus results not only in the opening of the claspers, but also in an everting and outward flaring of the hairpencils, thus presenting two arrays of scales that are structurally ideal to conduct, contain and disperse volatile substances (Fig. 3A and B).

The scales of the hairpencils are hollow with honey-combed walls. They are ca. 0.09 mm in diameter and vary in length from 40 to 85 μm (Figs. 4, and 5A and B). Thin-walled pores "portholes" of irregular shape from 0.1 to 0.5 μm in diameter can be seen on the external surfaces. Transmission EM photographs of cross-sections of hairpencil scales reveal that the portholes are covered by a very thin layer, believed to be cuticulin, supported by a fibrous, textured cuticle (Fig. 4E). When a modified scale is fractured at the base, an inner channel 0.7 μm in diameter is revealed (Fig. 4C). When the entire brush is removed with its adjacent integument, a single layer of columnar epidermal cells is observed to underlie the modified scales of the brush (Fig. 1B).

The lumen of each scale is continuous with a central cavity within an underlying epidermal cell (Fig. 5B). The base of each scale rests in a bulb-shaped socket which appears to be composed of rigid cuticle. At the junction of the lumen of each scale with the central cavity, there is a chromatin-like mass which stains heavily with alum haematoxylin (Figs. 2 and 5B) and chromatin-like particles are scattered within the oval pocket. A central tormogen cell is not distinct in

the mature adult but one may have degenerated. An active secreting (trichogen) cell forms a supporting cup-like pocket around what could be the remains of a tormogen cell. The trichogen cell is relatively large, extends inwardly and may be pushed to one side but always terminates with a large, dark-staining, basal nucleus (Figs. 1B and 2).

A histological study of the tissues underlying the cuticle of a hairpencil reveals that each organule possesses a basal bulb within a fibrous matrix which in turn is bounded by the microvillous membrane of the trichogen cell (Fig. 5). The microvillous membrane forms a cup-shaped enclosure within the trichogen cell. A reservoir is located at the center of the fibrous matrix. A much-convoluted plasma membrane is on the periphery of the trichogen cell where it is applied closely to the basement membrane which in turn separates the cell from the haemocoel (Figs. 2 and 5). The convoluted plasma membrane exposes a large surface area to extracellular fluids and in addition possesses coated vesicles (Fig. 6). Mitochondria and rough endoplasmic reticula are concentrated immediately within the convoluted membrane.

Discussion

The hairpencils of one- to three-day old *Grapholitha molesta* males have all of the histological and morphological features of a lepidopteran organ designed to continuously secrete, store and periodically dispense volatile chemicals. At rest, the pair of hairpencils are protected in pockets. Cross sections through these pockets provided an easy means of determining with light microscopy that the number of modified scales, hence organules, per hairpencil averaged 93. Though easily determined, the numbers of organules have not been reported for most other insects studied. Such counts might well serve as a means of comparison.

The term "organule" was introduced by Lawrence (1966) to refer to small integumental structures and to "cover all associations of small numbers of integumental cells which perform some specific function different from that of the general population of epidermal cells." In the hairpencils of *G. molesta* each organule consists of a modified scale with a lumen opening at the base through a cuticular pore continuous with a reservoir lined with microvilli located within a relatively large secreting trichogen cell (Fig. 2). These features are said to be common to scent glands of all lepidopteran males (Pliske and Solpeter 1971). The histological structure of insect organs with a similar function have been described for six genera: *Harpobittacus* (Crossley and Waterhouse 1969), *Phlogophora* (Birch 1970), *Danaus* (Pliske and Solpeter 1971), *Trichoplusia* (Grant 1971), *Manduca* (Grant and Eaton 1973) and *Ephesia* (Corbet and Lai-Fook 1977).

The location of the hairpencils varies considerably among insect species. In tortricid moths of the genera *Grapholitha* and *Pandemis*, hairpencils are located near the genitalia as in the butterfly *Danaus*. The hairpencils of *Pandemis* have, however, not been studied in detail. Unlike *Danaus* the bases of the hairpencils of *Grapholitha* do not occur on the end of a stalk when splayed but are everted from a cup-like invagination of the intersegmental membrane. Moreover, unlike *Danaus* when at rest, the bases of the tufts of hairs in *Grapholitha* are confined by the inverted integument in a manner which binds them into a tuft. The tufts of *Grapholitha* are protected within an intersegmental pocket formed dorsolaterally by the eighth abdominal tergite and ventrally by the ninth tergite. Like *Danaus* the bases of the hairpencils are formed by the intersegmental membranes between the eighth and ninth abdominal segments. The pockets not only provide a means of accumu-

lating secretion and protection from evaporation (Birch 1970) but, as indicated here, are of importance in protecting the delicate scales of the tuft from physical damage.

As has been determined in studies of other lepidoptera, the modified scales of each organule in *Grapholitha* are particularly well adapted to both store and rapidly dispense volatile material. Not only are the modified scales hollow but, in addition, their walls consist of a relatively thick porous network of delicate cuticle. The latter provides extensive surface with tiny compartments which appear to be capable of acting as sponges for the secretions. Such a porous wall has not been indicated to occur for other species. There is clearly no opening at the tips of the modified scales as Birch (1970) suggested might occur in some *Phlogophora* hairpencils. All compartments within the scale wall appear to be continuous and lead to portholes on the external surface.

The portholes are comparable in size to those of *Trichoplusia* ($0.5\ \mu\text{m}$) and *Manduca* ($0.4\ \mu\text{m}$). Unlike *Ephestia*, however, those of *Grapholitha* were always found to be covered by what appears to be the cuticulin.

The reticulate, outer surface pattern of the modified scales in *Grapholitha* differs from the long ridges occurring in *Trichoplusia*. In *Grapholitha* each porthole is bounded on all sides by a ridge. Material emanating through the cuticulin in the portholes might tend to adhere to and quickly evaporate from the greatly increased surface area. The same increase in blood pressure which causes the base of the hairpencil to evert would also tend to expel secretions through the portholes.

At the base of each scale, just below the cuticle, is a basal bulb, which presumably consists of cuticle. Such a structure has been used as a distinguishing characteristic of lepidopteran scent cells (Grant 1971). Its presence in *Grapholitha* is additional evidence that the hairpencils are odor producing.

Birch (1970) suggested that, because of the possible toxic nature of secretions, it is unusual for a secreting cell to serve as a storage reservoir. In *Harpobittacus* a "granular mass" separates the tips of microvilli from a reservoir. In *Grapholitha* the reservoir within and below the basal bulb is separated from the surrounding microvilli by an extensive fibrous matrix. A similar space of fibrous matrix has not been indicated for the genera *Phlogophora*, *Danaus*, *Trichoplusia*, *Manduca* or *Ephestia*. In *Grapholitha* this fibrous matrix appears to serve as a transient zone between the living, actively secreting cell and its non-living potentially destructive secretion. As indicated by the observed activities of male *Grapholitha molesta* the secretion of male pheromone appears to be continuous throughout life; hence, it may be hypothesized that the fibrous matrix is associated with such continuous secretion rather than secretion for only a limited period during development.

The large cell located at the base of each modified scale is typical of secreting cells of arthropods. It is relatively large with a conspicuous, basally-located nucleus. The cytoplasm is well supplied with mitochondria and ribosomes; the internal reservoir is lined with microvilli surrounding a fibrous matrix while the outer cell membrane is extensively infolded. Undoubtedly, such infolding provides an increased surface for exchange with the haemolymph. The occurrence of coated vesicles along the folded membrane, typical of pinocytotic uptake, is the first clear evidence of such uptake through this membrane in an insect hairpencil. This appears to be additional evidence that uptake and secretion may occur in *Grapholitha* as a continuous activity of these cells throughout the early life time of the insect rather than for only a very brief period during pupal development.

The organules of lepidopteran hairpencils are considered to be homologous to scales and conform to a common pattern of a trichogen cell with a microvillus-lined lumen; in addition there is a tormogen cell and a modified hollow scale with portholes which in turn articulate with a basal bulb (Corbet and Lai-Fook 1977). In *Grapholitha* the trichogen cell is easily recognized by the reservoir lined with microvilli and the extensive infolding of its outer surface. It may be postulated that the area of the inner lumen bounded by the microvilli may correspond to the remains of the atrophied tormogen cell. The tormogen cell may in turn form the pore connecting the lumen of the scale with that of the trichogen cell and subsequently the basal bulb, before atrophying. The darkly haemotoxylin-staining bodies at the base of each modified scale (hair) may represent the remains of the nucleus or some other part of the degenerated tormogen cell. Similarly, other bodies within the cuticular socket and within the fibrous space may represent the remains of the tormogen cell. Verification of these postulates will have to await developmental studies on this or some similar insect.

The morphology, histology and fine structure of the organules of the hairpencils of *G. molesta* support the behavioural observations of Baker and Cardé (1979) that males of *G. molesta* continually secrete a male sex pheromone which is stored and dispensed in short bursts just prior to copulation.

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Abbreviations

7S	seventh abdominal sternite	H	haemocoel
7T	seventh abdominal tergite	HP	hairpencil tuft
8S	eighth abdominal sternite	L	lumen of modified scales
8T	eighth abdominal tergite	M	folded membrane
9T	ninth abdominal tergite	MT	mitochondrion
B	basal bulb	MV	microvilli
BHP	broken scale of hairpencil	N	nucleus of secreting cell
BM	basement membrane	P	retractable pouch in flexible integument
BS	socket of basal bulb	PO	porthole
C	outer surface of cuticle	R	reservoir
CC	central cavity	RER	rough endoplasmic reticulum
CE	cells at base of hairpencil	RT	reticulation on outer surface of modified scale
CL	left clasper	S	modified scale or "hair"
CM	chromatin-like mass	SC	secreting cell
CV	coated vesicle	T	closed tip of modified scale
D	duct from cell reservoir	W	wall of modified scale
E	everted sclerite		
FS	fibrous space		

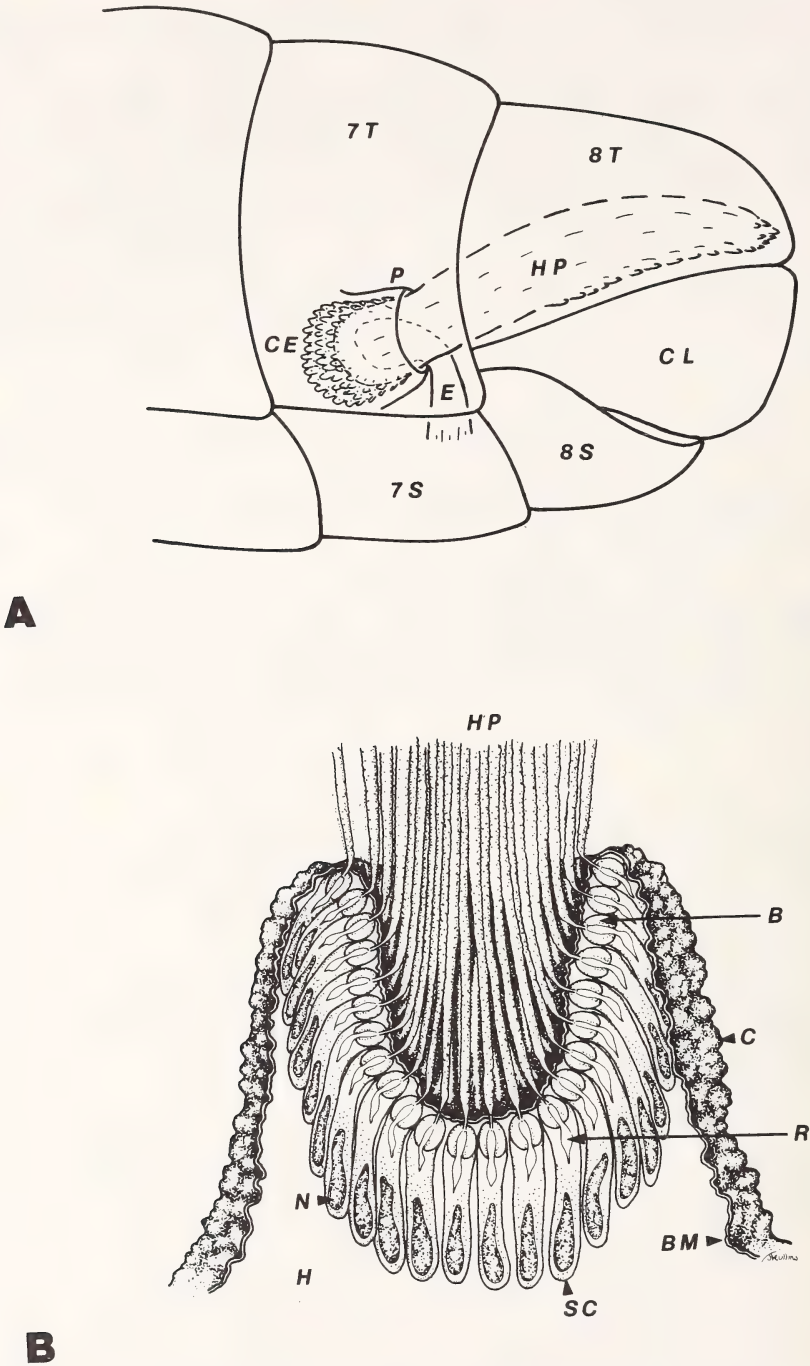


FIG. 1. A, Diagram of the left, posterior end of the abdomen of male *G. molesta* showing the position of the hairpencil at rest. X80. B, Diagram of longitudinal section through retracted pouch of a hairpencil. X375.

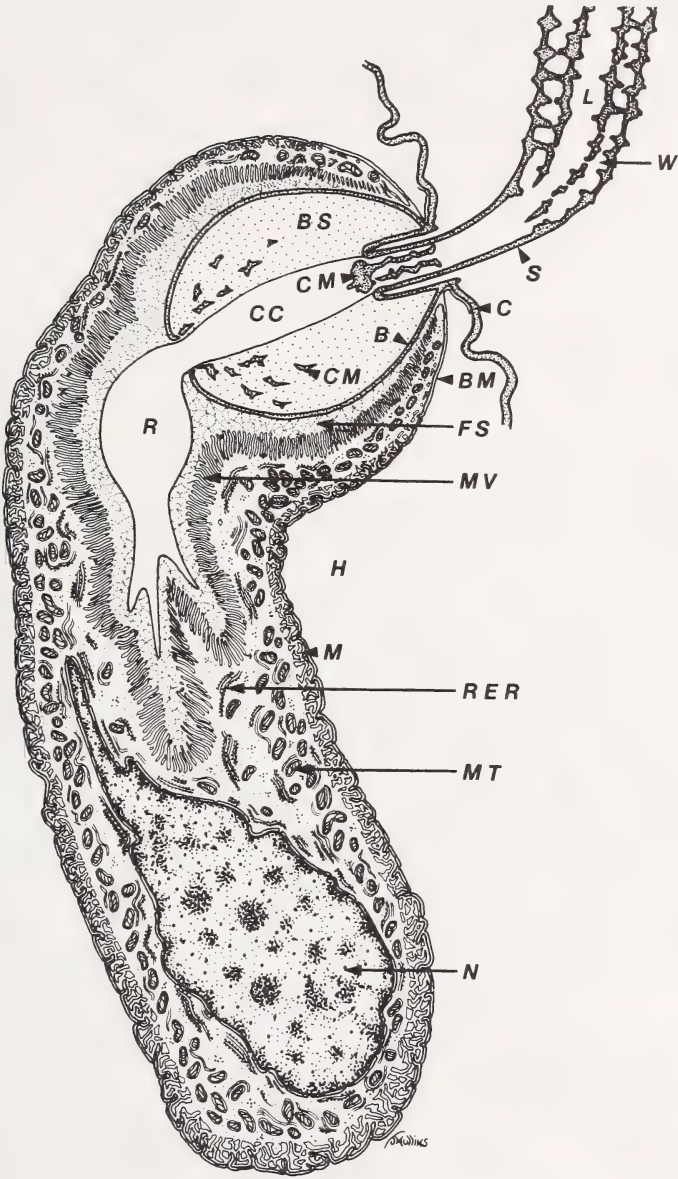


FIG. 2. Diagram of a single organule of a hairpencil. X2,400.



FIG. 3. A, Dorsal aspect of partially extended left hairpencil. SEM X145. B, Lateral view of everted pouch of hairpencil. SEM X1,000.

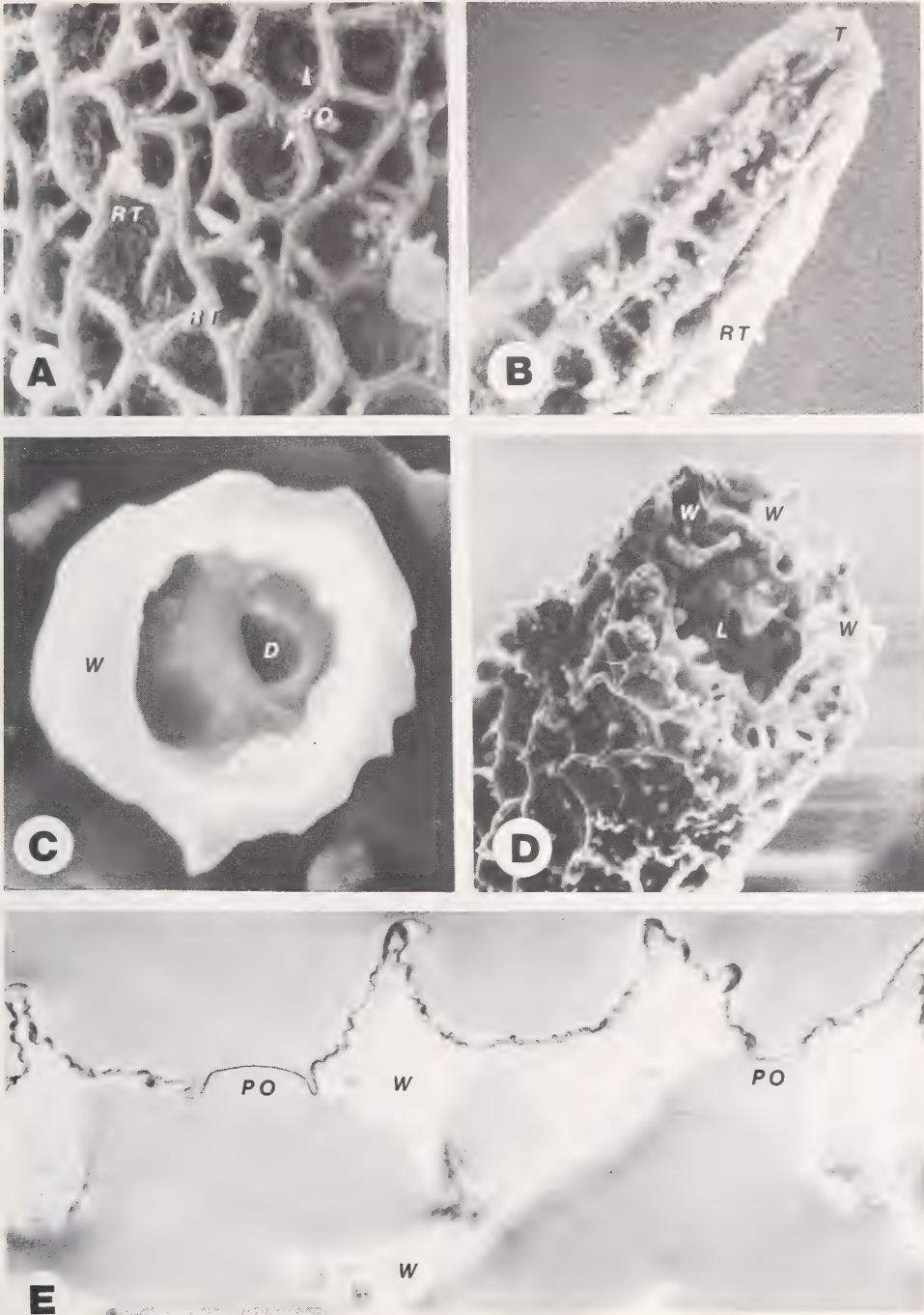


FIG. 4. Details of a modified scale which comprises the brush of a hairpencil; A, Outer surface of scale. SEM X10,000. B, Tip of modified scale. SEM X6,000. C, View into base of fractured scale of hairpencil. SEM X13,000. D, Scale of hairpencil fractured at midpoint. SEM X6,000. E, Section of scale wall showing outer edge. TEM X50,000.

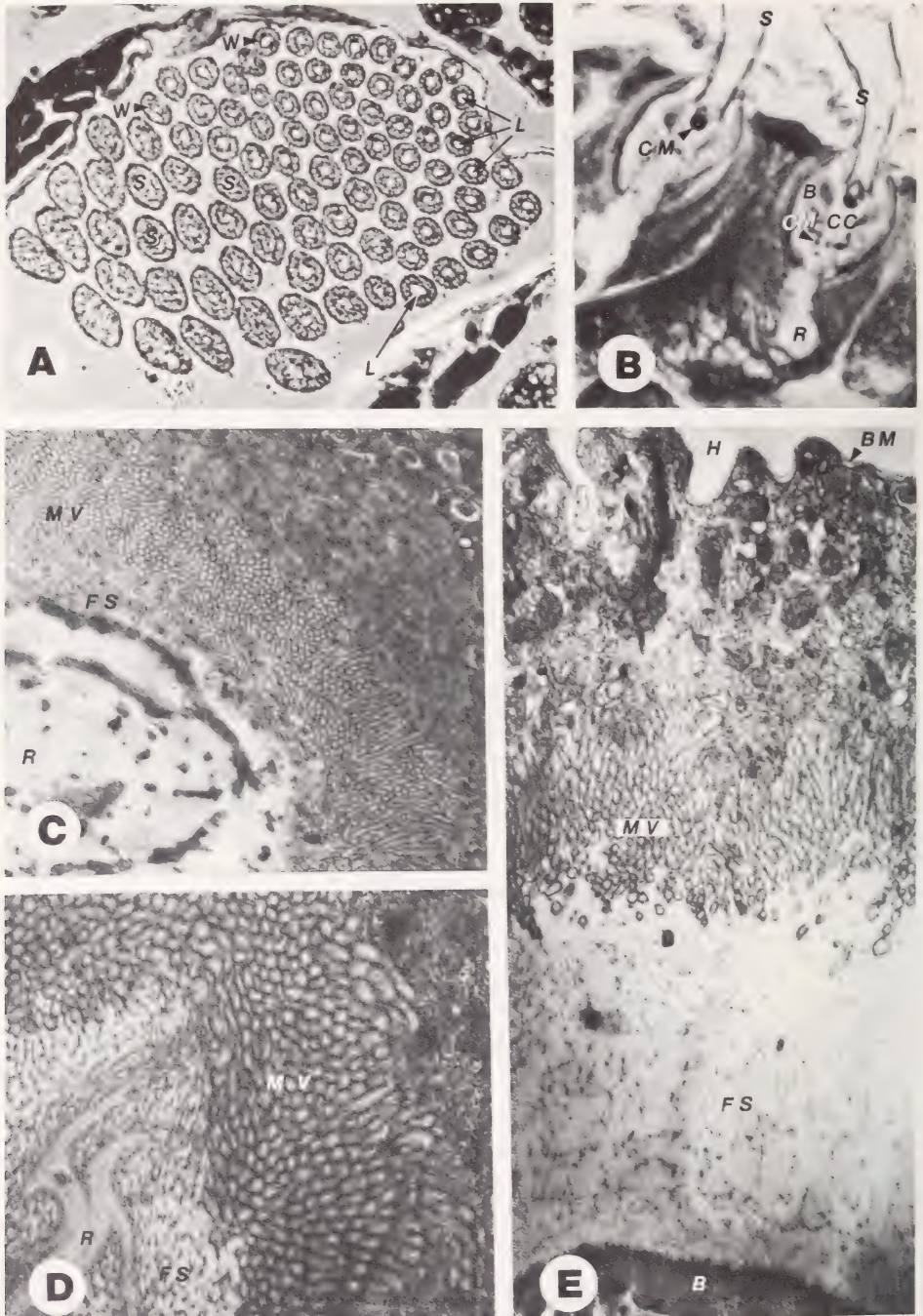


FIG. 5. A, Cross section through modified scales of a single hairpencil. LM X625. B, Longitudinal section through bases of two organules. LM X1,300. C, Cross section of organule just below basal bulb. TEM X11,000. D, Cross section through organule near inner end of reservoir. TEM X24,000. E, Cross section through basal bulb area of an organule. TEM X20,000.

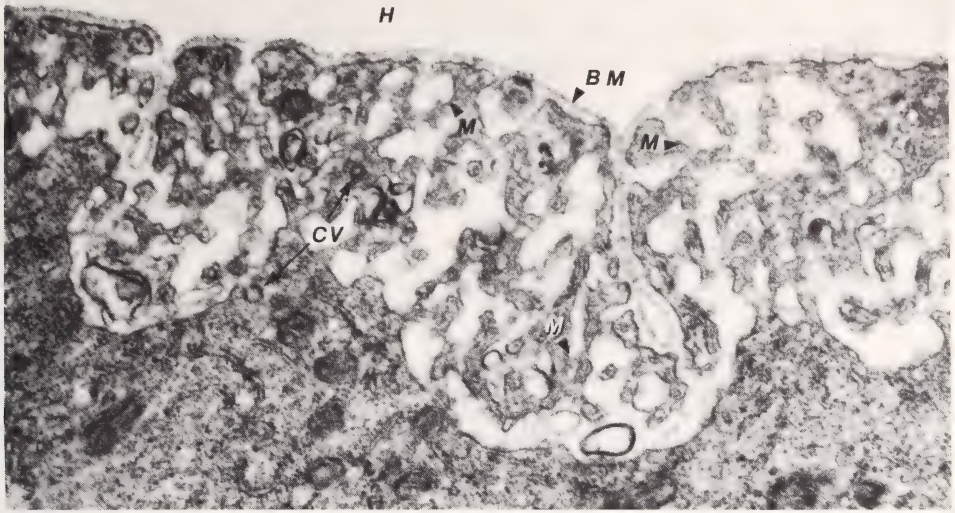


FIG. 6. Extensively folded basal membrane of secreting cell of an organule. TEM X34,000.

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**RELATIONSHIPS BETWEEN DEGREE-DAYS AND COMPUTER
SIMULATED EVENTS WITHIN A POPULATION
OF THE EUROPEAN RED MITE,
PANONYCHUS ULMI (ACARINA: TETRANYCHIDAE)**

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Abstract

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The dates of population events in the seasonal development of the European red mite, *Panonychus ulmi* (Koch), were estimated for 10 successive years for three apple growing areas in Ontario using a validated simulation model and temperature records. The average number of degree-days (DD) from 1 March to each simulated event was determined for each area. Simulated 1st and 2nd generation events within a population occurred within three days of that of the DD index, events after the 2nd generation occurred within four days of the index. For observed 1st and 50% hatch of overwintered eggs, the indices were within 5 DD of actual accumulations at Vineland in 1976 and 1977. Indices for events occurring later in the season at most differed from actual accumulations by 97 DD in 1976 and 17 DD in 1977.

Introduction

Accumulated degree-days (DD) which are relatively easy to compute, have been widely used as indices to predict dates of pest emergence in the early season (Hagley *et al.* 1978; Trottier and Herne 1979). DD indices for predicting the times of peak numbers of the immature stages of mites would be a valuable aid in optimizing the timing of chemical control for these important orchard pests.

Acaricide sprays for control of the European red mite (ERM), *Panonychus ulmi* (Koch), are most effective when timed against peak numbers of immature stages (Herbert 1970). The time of 50% hatch of winter eggs is the first of many distinct periods of peak numbers of immature stages that occur in each generation throughout a season. In southern Ontario, Trottier and Herne (1979), found that the 1st hatch of ERM winter eggs occurred at ca. 150 DD > 5.5°C. However, as the ERM has 6 to 8 overlapping generations a year, it is difficult to correlate population events after those of the first generation, such as peak numbers of 2nd-generation mites, with the corresponding DD accumulations. Even with daily sampling it is difficult to separate generations.

Experiments to develop a simulation model of the life history of ERM (Herne and Lund 1979), showed that the developmental rate of the mite was more accurately described over a wide temperature range by an exponential function rather than a linear function. Thus the number of DD required for an event in any generation is not constant, but is dependent on the range of temperatures to which the population has been subjected. Our model, based primarily on daily temperature, simulates the daily development of all life stages of the mites during a season, and therefore a relationship between any particular population event and accumulated DD can be easily determined.

In this paper we describe the use of our simulation model for estimating DD

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indices to predict different events in populations of European red mite. These indices will be useful when planning control strategies for mites.

Methods

The computer program of the ERM simulation model of Herne and Lund (1979), computes daily numbers of eggs, young, adults, and combinations thereof within a population. The numbers generated depend on the initial size of the population and daily temperatures, which are the only other input required. A revision of this model requires as input only an arbitrary number of winter eggs, and daily maximum and minimum temperatures starting from 1 March for any given climatic region. Using this information, theoretical tables of the numbers of different life stages present each day for the years 1969 to 1978 were computed for each of 3 different climatic regions of Ontario where apples are grown, viz., Harrow, Vineland and Thornbury.

The daily number of DD from 1 March to each successive date in the season was calculated by integrating with respect to t (time):

$$g(t) = \begin{cases} a_1 + r_1 \cos(2\pi t) & \text{for } 0 \leq t \leq 0.5 \\ a_2 + r_2 \cos(2\pi t) & \text{for } 0.5 < t \leq 1 \end{cases}$$

above 5.5°C . The constants a_1 , a_2 , r_1 , r_2 are defined as follows:

$$\begin{aligned} 2a_1 &= \max_1 + \min & 2a_2 &= \max_2 + \min \\ 2r_1 &= \max_1 - \min & 2r_2 &= \max_2 - \min \end{aligned}$$

where $g(t)$ represents temperature at any time during the day, $\max_1$, $\max_2$ are maximum temperatures on two successive days, $\min$ is the common minimum, $t = 0$ is equivalent to the beginning of the 1st hour of the physiological 24-h day, and $t = 1$ is equivalent to the end of the 24-h day. For each of the three areas and each of the ten years, it was then possible to relate a particular simulated event within a population with a corresponding number of accumulated DD. The DD index for a particular event within a population in each area was estimated by averaging the ten, yearly DD accumulations corresponding to that event.

The number of days between the date a simulated event occurred and the date of the 10-year average or index was calculated also for each area and year. For example, the simulated peak of the immature stages in Vineland in 1972 occurred on 9 July. The DD index for Vineland corresponding to this F_2 peak was 644. In 1972, 644 DD had accumulated by 6 July, giving a three-day discrepancy from the 10-year average. The mean and standard deviation of each of these discrepancies were calculated to indicate the reliability of the DD indices (Table I).

Results and Discussions

The relationships between accumulated DD $> 5.5^\circ\text{C}$ and different events within a population as generated by the simulation model are shown for all three climatic regions (Table I).

The variability between years in DD accumulated to the day of occurrence of any simulated event may be explained mainly by two factors; (1), DD accumulated at different temperatures are not equal in their effect on development of ERM populations, i.e. one DD accumulated at a temperature of 10°C does not have the same effect as one DD accumulated at 20°C (Herne and Lund 1979); and (2), the year to year variability in weather, especially temperature.

TABLE I. Degree day indices for different events in the seasonal development of *P. ulmi* populations in 3 climatic regions of Ontario, determined with a simulation model, and mean and standard deviation of yearly discrepancies from these indices.

Population event	Harrow			Vineland			Thornbury		
	DD ^a index	Discrepancy (Days) ^b		DD ^a index	Discrepancy (Days) ^b		DD ^a index	Discrepancy (Days) ^b	
		Mean	S.D.		Mean	S.D.		Mean	S.D.
1st Hatched ^c	157	0.5	0.97	148	1.0	0.66	153	0.9	1.20
50% Hatched ^c	248	0.8	0.42	239	0.8	0.42	239	0.4	0.70
99% Hatched ^c	393	1.2	0.79	380	1.1	0.74	384	1.1	0.88
F ₁ 1st ♀	291	1.2	1.32	261	1.0	1.15	283	1.1	1.10
F ₁ peak ^d	330	1.3	1.06	318	0.8	0.63	320	0.6	0.70
F ₂ 1st eggs	326	0.6	0.84	288	1.1	1.20	316	0.7	0.68
F ₂ egg min.	650	1.2	1.23	639	1.4	1.26	653	1.0	0.82
F ₂ peak ^d	656	1.2	0.42	644	1.4	1.35	654	1.0	0.82
F ₃ egg min.	938	1.3	0.95	925	1.1	1.00	968	1.0	1.05
F ₃ peak ^d	953	1.1	1.37	933	1.0	1.05	982	1.4	1.35

^a DD index = mean number of accumulated DD > 5.5°C, based on 10-years of data.
^b Mean discrepancy = average number of days between date of occurrence of the simulated event and date of occurrence of DD index.
^c Overwintered eggs.
^d Young and adults.

Random differences in fecundity and mortality were not considered in calculating the variability between years. Preliminary simulations with random numbers indicated that variability due to these factors was negligible.

Calculations showed that in 19 cases out of 20 the simulated early-season events should occur within three days of the date obtained by using the DD index, and within four days for events later in the season.

A comparison of the calculated indices for first and 50% hatch of overwintering eggs with the DD accumulated on dates of these same events in 1976 and 1977 at Vineland (Table II) reveals that first and 50% hatch occurred within 5 DD of our calculated indices in both years. These indices agree closely with those determined experimentally by Trottier and Herne (1979), i.e. 155 and 250 DD respectively.

TABLE II. Degree day indices (DD) for different events in a population of *P. ulmi* as estimated by simulation compared with DD accumulated on dates of observed events in 1976 and 1977 at Vineland.

Population event	DD ^a index	Accumulated day degrees on date of observed event ^b	
		1976	1977
1st Hatched ^c	148	147 (19 April)	145 (25 April)
50% Hatched ^c	239	239 (12 May)	244 (14 May)
F ₁ Peak ^d	318	330 (28 May)	311 (19 May)
F ₂ Egg min.	639	680 (24 June)	635 (18 June)
F ₂ Peak ^d	644	680 (24 June)	650 (19 June)
F ₃ Egg Min.	925	1020 (17 July)	940 (9 July)
F ₃ Peak ^d	933	1030 (18 July)	950 (10 July)

^a 10-year average, based on simulations for years 1969 to 1978.

^b Based on daily sampling.

^c Overwintered eggs.

^d Young and adults.

The accuracy of predictions for later events in the population was generally good; DD accumulations for observed events up to and including the peak of the immature stages of the 2nd generation were within 41 DD of the appropriate indices at Vineland in 1976. Because the weather in 1976 was generally cool compared to the 10-year average, the egg minimum and peak of the immature stages of the 3rd generation occurred ca. 100 DD later than the appropriate indices, or 7 days later than expected. In 1977 the weather was only slightly cooler than the 10-year average and there was closer agreement for all events (± 17 DD). In a cooler year a particular event generally requires more DD, and conversely in a warmer year fewer DD than average (DD index).

Our study demonstrates the usefulness of a simulation model to estimate bioclimatic indices for predicting peak numbers of various stages of naturally occurring ERM populations. These bioclimatic indices should improve the timing of control measures for the ERM. The method reported here should prove useful in developing similar indices for other orchard pests.

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**A SIMULATION MODEL FOR THE SURVIVAL AND DEVELOPMENT
OF THE ONION MAGGOT**
HYLEMYA ANTIQUA (DIPTERA: ANTHOMYIIDAE)¹

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Abstract

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A computer model was developed to simulate the interaction between populations of the onion maggot, *Hylemya antiqua* Meigen, and a hymenopteran parasitoid, *Aphaereta pallipes* Say. The simulation used previously published data from many sources to set in motion a chain of time-varying delays with attrition. In this way, a continuous-time model was approximated. When varying abiotic and biotic parameters were entered, the system produced an array of outputs that were used to elucidate the central dynamics of the ecology of these organisms in various environments. Population density, weather, planting arrangement, insecticide use and timing of insecticide applications could all be manipulated in order to investigate their effects. An evaluation of accuracy and sensitivity of model behavior was made in the preliminary stage of analysis using simple interactions (i.e., parasite-host, density-yield).

Introduction

The onion is one of the most important vegetable crops grown for consumption as green or mature bulbs in all sections of the United States (Wyman 1972). In 1976, onion production in the U.S.A. totalled approximately two billion pounds (Haynes *et al.* 1979). The more important areas of commercial production are Texas, California, New York, Michigan, Colorado, Idaho and New Jersey.

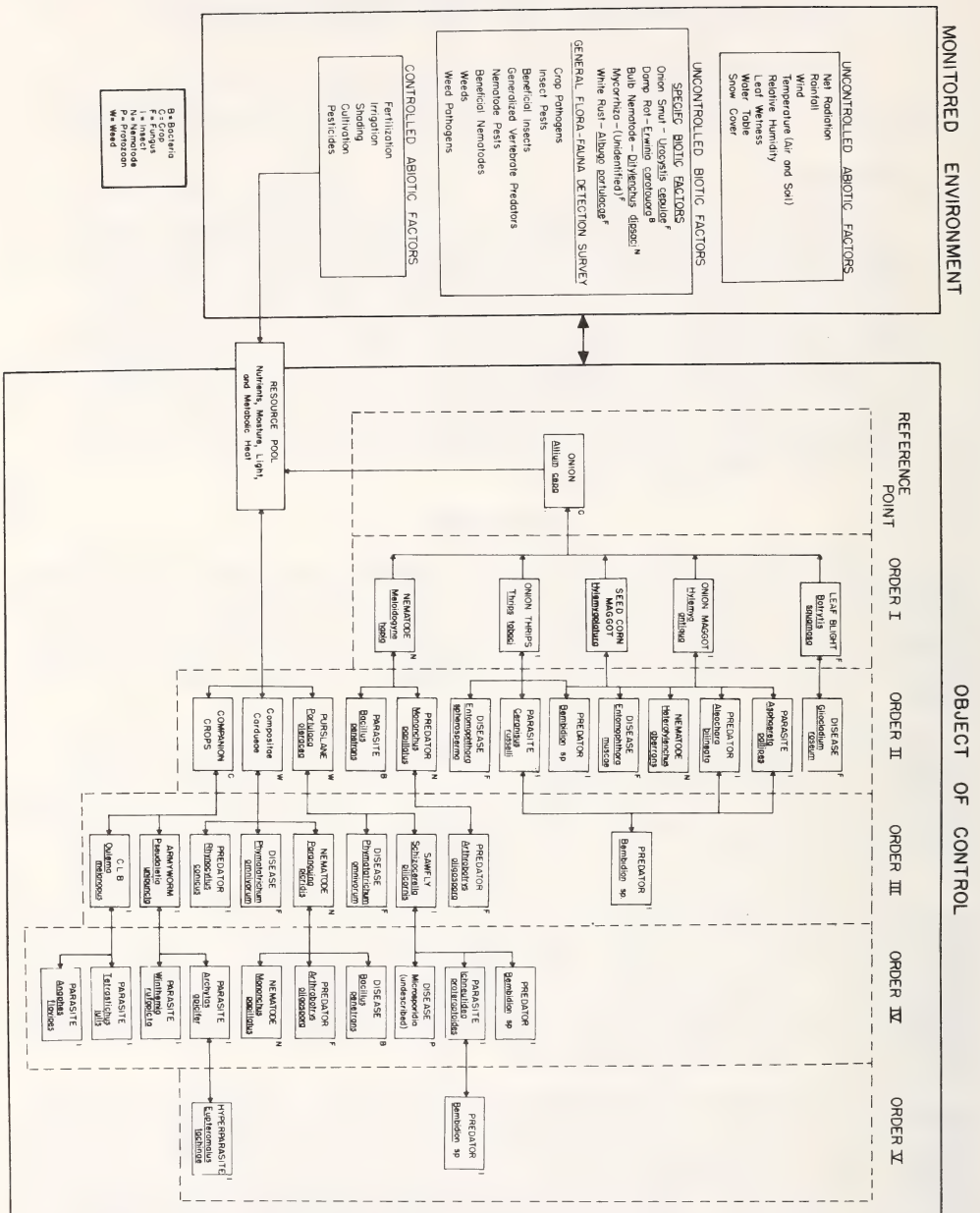
Onion growers in the U.S.A. are in an uncertain situation regarding the control of the various pests of onion. The protection of this crop continues to depend on the heavy use of pesticides. However, the economics of developing new pesticides, the resistance to existing ones, and an awareness of detrimental effects on the environment are forcing a reexamination of present-day controls.

The failure of long-term control of the onion maggot, a major insect pest of onions can be depicted through an historical account of the pesticides used since the 1930's (Haynes *et al.* 1979). The thiophosphate, fonophos, is presently used in most areas for control of the onion maggot (including Michigan, New York, and Ontario). Although adequate control is still obtained with fonophos, it may follow the course of the previously recommended material, fensulfothion, which became ineffective through repeated use.

Because pest control in the onion system lacked an ecological basis, a sub-model of an onion system was developed. The model served as a research tool for identifying areas where more information was needed. It also served as a comprehensive review of the literature and as a catalyst which forced us to examine the types and effects of a variety of control strategies. Designing the model and identifying the various parts of the system involved a process of breakdown reiteration, and testing that enabled us to view and work with the complex onion

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system. However, due to an insufficient data base, it was not possible to construct a complete model (Fig. 1). Consequently, a sub-component of the conceptualized system was chosen to be modeled. This sub-component consisted of the onion maggot, the onion plant and a braconid parasitoid of the onion maggot. It was chosen because a good understanding of it was necessary to explore management alternatives.

The onion maggot, its parasitoid and the onion bulb were the biological variables of the model. Abiotic variables of the model were soil and foliar pesticides, weather and time. These variables were used to construct a model that would show the distribution of maturity for the organism at any point in time. As a corollary of this, it would show the damage to onions that occurs given various abiotic and biotic conditions. The model was constructed so that the control strategies could be evaluated without having to change the structure of the model. It was also necessary to insure that the models could be coupled to other components of the system (presently in preparation) with little revision to the basic model.

The Model

The conceptualized model (Fig. 2) had controllable inputs: weather (three different weather sets from Lansing, Ludington, and Houghton, MI), parasitism (*Aphaereta pallipes* Say), planting density, type of pesticide, frequency of pesticide use, initial date of application of pesticide, and spring density of onion maggot pupae. The outputs of the model are yield (amount per acre), net profit, and the number of individuals in each age class (for each organism). The model was judged a success if there was good correlation between output and field observations.

In formulating the model, a one-acre field of onions was considered. It was thought that the size of the field would have no bearing on the dynamic interactions that were taken into account by the model. With minor modification, any sized field could be implemented into the model structure. This assumption was based on two restraints that were built into the model. First, no immigration or emigration would take place with the onion maggot or the parasitoid component (closed system). Second, growth of the onion bulb would be based on a static regression model that would result in uniform growth for all onions. These restraints enabled the model to elucidate the interactions independent of the size of fields. The economic section of the model was a static submodel in that the cost of labor and materials, as well as marketability of the crop, remained constant through time. This was not detrimental to the workings of the model since it provided a standard measure where comparisons between simulation runs could be made quickly. A dynamic model, although being more realistic, may not be as useful in analyzing the population dynamics of the various organisms.

The construction of a model detailing the relationships between abiotic parameters and pesticide effectiveness and breakdown was not undertaken due to the complexity of such a system. Instead, it was assumed that data on average, half-life tendencies of certain pesticides approximated most pesticide behavior over a wide range of weather conditions (F. Matsumura³ and A. Wells⁴, personal communication). A number of restrictions or assumptions were incorporated into components of the model concerning the population dynamics of the onion maggot

³ Dr. F. Matsumura, Pesticide Res. Cen., Mich. State Univ., February 1978.

⁴ Mr. A. Wells, Dept. of Entomology, Mich. State Univ., December 1977.

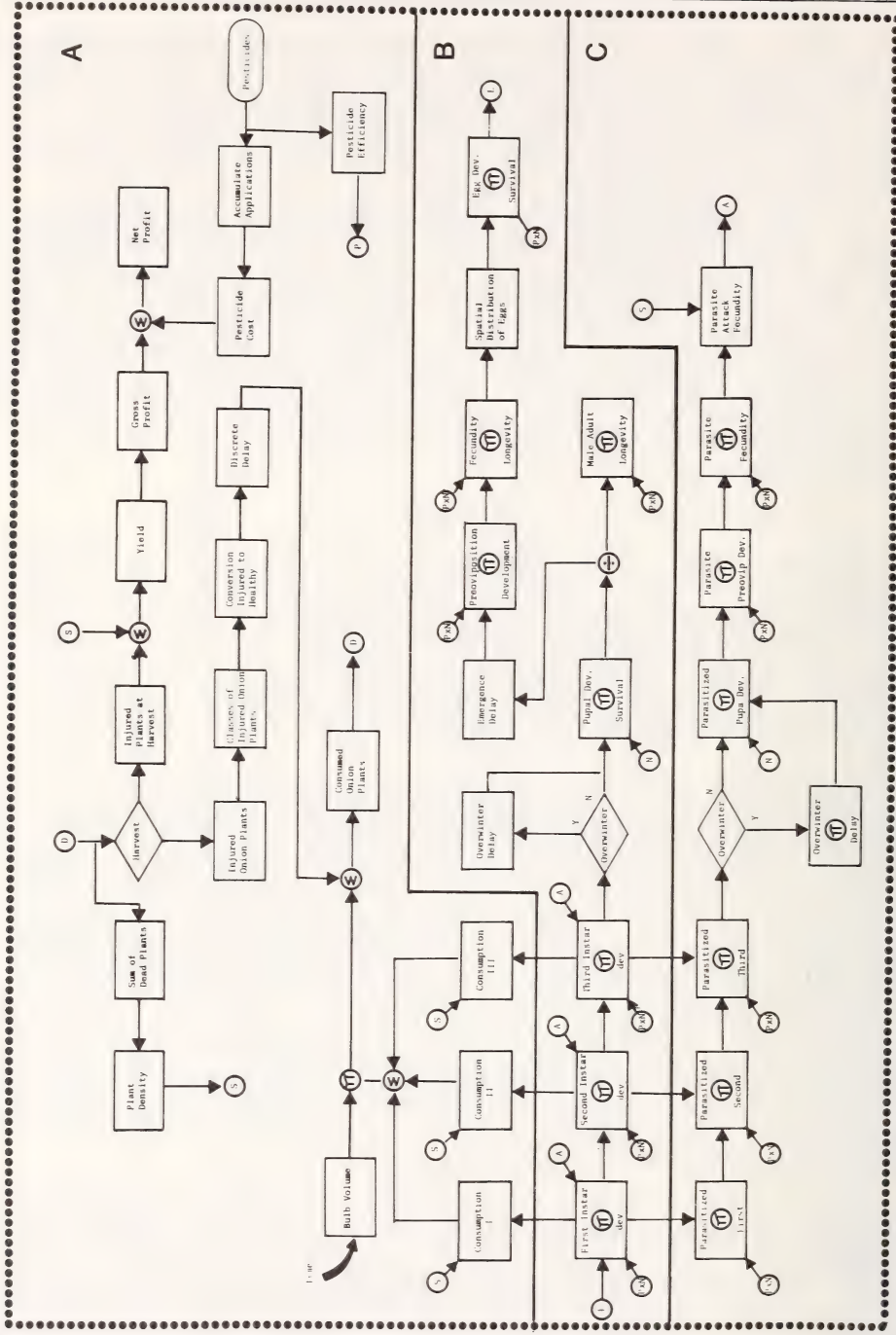


FIG. 2. Functional diagram of the life system of the onion maggot (S = spacing of onions, D = dead onion plants, P = mortality due to pesticides, E = eggs, A = parasitism, N = natural mortality). A, submodel of the onion, pesticide, and economics components; B, submodel of the dynamics of the onion maggot population; C, submodel of the dynamics of the parasitoid population.

and parasitoid. Assumptions that applied to all the organisms were: (a), mortality was not age specific in each age class, but was distributed uniformly; (b), the reaction of all life stages to temperature was instantaneous; (c), there were no after-effects in the temperature reaction; and (d), development was temperature dependent. No age specific mortality was assumed because no pertinent information on this topic was found in the literature. It was felt that the best approach was to treat mortality uniformly across the life stages until research dictated otherwise.

Presently, assumptions (b) through (d) form the basis for most models on the population dynamics of insects (R. Rabinge⁵, personal communication) (Fulton 1978). More specifically, the data of Ellington (1963) and Salkeld (1959) suggest that these temperature relationships hold true for the onion maggot and *A. pallipes*.

Temperature had the most widely distributed effects in this model. It was input to a number of functions that affected adult emergence, oviposition, survival and length of stay in a life stage. Temperature data from the National Weather Service was supplied in the form of daily maximums and minimums. The time sequence of the model was in tenths of days, each tenth or 2.4 hours representing a DT (i.e., Δt). In order to calculate an average temperature for each DT, temperature changes within a day were assumed to be sinusoidal with the maximum and minimum twelve hours apart (Fulton 1978). Average air temperature = $\text{Min} + [(\text{Max}-\text{Min})/2] + [(\text{Max}-\text{Min})/2] * [\cos(s)]$ where $s = \text{Time} * 3.1416$

These calculated temperatures, when used to determine degree-day accumulations, produced errors that were insignificant when looked at over an entire season (Baskerville and Emin 1969). Heat units or degree-days were used to synchronize emergence, to place gravid onion maggot females in the correct fecundity class, to regulate the numbers of onion maggot pupae going into diapause, and to evaluate the model's performance (by comparing observed simulation results with field data).

$$\text{Degree days} = F(t) = \text{Max}[0, T(t) - T_0] * \text{DT}$$

where $T(t)$ = temperature at time t

T_0 = threshold temperature

and heat accumulation in degree-days, TDD, is

$$\text{TDD} = \int_0^x F(t) dt$$

where x represents the mean number of calendar days required to complete development in a life stage.

Regression analysis between degree-day accumulations for air and soil have been shown to give coefficients of determination, R^2 , from .86 to .96 in mineral soils (Lampert 1976). Bath (1975) developed a soil-air temperature model for muck soil of uniform particle size, with a slope of less than 2% and for a depth of four inches.

$$sT = 16.41966 + .750848 * \text{average air temperature}$$

$$r^2 = .69$$

This regression equation was used to predict soil temperatures (sT) from air temperatures when needed for egg, larval, and pupal development.

⁵ Dr. R. Rabinge, Agric. Inst., Wageningen, Netherlands, January 1978.

The main structure of the model could be viewed as a union of three main biological components. These represented the submodel of the onion, pesticide, and economics components (Fig. 2A), the submodel of the dynamics of the onion maggot population (Fig. 2B), and the submodel of the dynamics of the parasitoid population (Fig. 2C). Using components was felt to be the ideal method for constructing a model of a smaller subsystem so that the model could be expanded by interfacing components without drastically restructuring the model. Table look-up functions (Llewellyn 1965) were used in all three components for linear interpolations between data points in each entry and linear extrapolation below and above the minimum and maximum values for each data set. The function approximation by linear interpolation is given by Manetsch and Park (1977) as being:

$$FNL(X) = DVAL(I) + [(XD - (I-1) * DX) (DVAL(I+1) - DVAL(I))] / DX$$

where FNL = desired approximation to function,

DVAL = array that represents values of the function $F(\cdot)$ at $N+1$ intervals of independent variables,

XD = difference between $(X - X_S)$ (difference between independent value X and its smallest value X_S).

DX = interval between independent values.

The density of onions per acre available for consumption by the onion maggot was a function of within-row spacing, specified by the user.

$$NO = 22366 * 12 / SPC$$

where NO = number of onions per acre,

SPC = spacing of onions (in inches) within a 2-row bed.

Onion consumption by each larval stage was determined at the end of every ten DT's (one day). Consumption rates were based on data by Workman (1958) and scaled according to the larval instars involved. Consumption by all instars was then summed and subtracted from the number of onions left in the field, given the size of the onion bulbs at that time.

The relationship between larval consumption (volume of onion consumed) and bulb diameter is as follows:

$$\text{First instar consumption} = .196 e^{-.85 * BD}$$

$$\text{Second instar consumption} = .4 e^{-.85 * BD}$$

$$\text{Third instar consumption} = 6.75 e^{-1. * BD}$$

where BD = bulb diameter (G. Bird⁶, unpublished data).

It was assumed that all available onions in the field were the same size at any one point in time and bulb volume was obtained from using the table look-up function for any specific date.

$$\text{bulb volume} = .002 e^{(.09 * \text{days after seeding})}$$

The number of killed onions (NK) was determined by dividing the total

⁶ Dr. G. Bird, Dept. of Entomol., Mich. State Univ., E. Lansing, MI, 1976.

volume of onions consumed by all instars by the present onion volume per bulb. From this, the number of damaged onions was determined (Loosjes 1976):

$$ND = 1.9 \times NK$$

where ND = number of damaged onions per day,
NK = number of killed onions per day.

Damaged onions were assigned a per cent damage according to a negative exponential equation where 50% of the damaged onions (ND) were assumed to be 90% consumed.

$$NO = NO + (ND \times .5) \times .1, .2, .3, .4, .5, .6, .7, .8, .9.$$

This gave a damage distribution of nine classes for the partial consumption of onions. The remaining onion volume within these classes was available for consumption the next day. The per cent of volume not consumed was converted back to healthy onions, based on the assumption that the larva usually disperses after the onion has been consumed. Calculation of this number of damaged onions was necessary as an input for the economic subcomponent.

Furrow and foliar insecticide applications were available management options. An in-furrow application that inflicts 98% mortality on all larval stages (A. Wells⁷, personal communication) can be made at planting time. A foliar spray directed at the adult onion maggot may also be applied at various times during the season. Depending on the particular spray, the mortality of the flies and *A. pallipes* follows an exponential decay curve with a half-life of one, two or four days (F. Matsumura⁸, personal communication).

$$PMORT = 1.0 - .96 * EXP((-CPDAY) * (.69314/FREQ))$$

where PMORT = mortality due to insecticide spray,
CPDAY = number of days between sprays,
FREQ = residual effectiveness of spray applied
(Malathion - 1 day, Parathion - 2 days, Diazinon - 3 days).

At harvest the total number of onions remaining in the field (NO) was converted to 100 pound quantities (440 onions per cwt) and multiplied by the market price (\$6.00) to give a gross profit for the end of the growing season. The net profit was obtained by deducting the costs of any pesticides used and the fixed costs of production, estimated to be \$1200.00 (C. Cooper⁹, personal communication), from the gross profit.

$$NETP = ((NO/440) * 6.0) - (CF + CS) - 1200.$$

where NETP = net profit,
NO = number of healthy onions remaining in field,
CF = cost of a furrow insecticide,
CS = cost of foliar insecticide.

It was found that the developmental period of a population of organisms was distributed over time. That is, for the aggregate flows, individuals have different lag times; therefore, while individuals may enter the process at the same time, the output flow will be distributed over time. This was usually due to genetic differences among individuals and variable conditions in the microclimate. A method

⁷ Mr. A. Wells, Dept. of Entomol., Mich. State Univ., E. Lansing, MI, Dec. 1977.

⁸ Dr. F. Matsumura, Pesticide Res. Cen., Mich. State Univ., E. Lansing, MI, Feb. 1978.

⁹ Mr. C. Cooper, Coop. Ext. Ser., Mich. State Univ., E. Lansing, MI, 1976.

of modeling this type of aggregative behavior can be performed by using time-varying, distributed delays (Manetsch and Park 1977).

The basic assumption in using time-varying, distributed delays to simulate insect development was that the time required for development of a specific stage had an associated mean and variance for a temperature regime. Depending on the shape of the probability density function of the particular process, the parameters D and K were chosen, such that D was the mean lag time, $D = D(t)$, and K described the shape of the distributed variable.

When modeling a continuous process as opposed to a discrete one, the assumption is made that mortalities, dependent on temperature, operate continuously. This implies that:

$$P_t = P_o e^{at}$$

where t = time,
 a = instantaneous survival,
 P_o = initial population,
 P_t = population at time t .

Fulton (1978) developed the idea of instantaneous survival being a linear, exponential relationship with temperature. This idea enabled mortalities to be implemented in the delay technique.

In trying to apply a survival function over the entire life stage, a complication arose since the time spent within the stage was also a function of temperature. The interaction was eliminated by using the instantaneous survival rate as the proportional loss rate.

$$P_t + DT = P_t e^{(PLR)}$$

where $PLR = a + b * \text{temperature}$

The instantaneous survival rate was used to compute half-lives of the individuals under the existing temperature regime. By setting $P_t/P_o = e^{at} = 1/2$, the half-life became $t = -(1 \ln 2/a)$. This half-life represents a median survival time.

The following relationships between instantaneous survival and temperature were used in the model:

egg survival = $.16 - .03 \text{ temperature}$,
 first instar survival = $1. - .02 \text{ temperature}$,
 second instar survival = $.5 - .01 \text{ temperature}$,
 third instar survival = $.11 - .002 \text{ temperature}$.

The onion maggot component was responsible; (a), for simulating the passage of individuals through the various age classes, (b) for simulating the effects of different mortality factors, and (c), for supplying the other components with numbers of onion maggots in various age classes. Two important assumptions were made: (a), density-dependent relationships did not operate in the onion maggot system; and (b), all female adults were mated and fertilized. These assumptions were made because of insufficient data.

The time-varying, distributed delays, for aggregates moving through the age classes, were dependent on the mean developmental times. The onion maggot component for the most part was executed on a per DT basis. The mortality acting within the developmental stages was a product of the "natural" temperature dependent mortality and the mortality due to pesticides. These were assumed to be independent events. The pupal mortality depended solely on soil temperature.

The overwintering delay represented the number that entered diapause. The subroutine "diapause" converted pupae to diapausing pupae, depending on degree-day accumulations. The three generations were tracked by accumulating degree-days. Ten, 67 and 100% of the pupae were put into diapause from each generation, respectively (Perron 1972).

Degree-days were also used to place mature females into fecundity classes. The number of eggs oviposited by a gravid female was tied to the temperature regime that the individual was exposed to during preoviposition (Loosjes 1976). The approximate length of the preovipositional period for onion maggot is 120 degree-days. This was calculated by:

$$\text{TOTAL} = \text{TOTAL} + [2.0 * \text{MAXTEMP} (I) + \text{MINTEMP} (I)] + [\text{MINTEMP} (I+1)]/4.0$$

where TOTAL = sum of average daily temperatures of preovipositional period (120 degree-days)

Five fecundity delays were used at 50, 60, 70, 80 and 90°F. If a group of females underwent preovipositional development between 45 and 55°F, they were put into the 50°F delay. Similarly, if an aggregate of females were exposed to an average temperature of 74°F during preovipositional development, they were put into the 70°F delay, etc.

$$\text{BIN} = (.5 + \text{TOTAL}/S/10.0) - 4$$

where BIN = developmental class (1,2,3,4 or 5, corresponding to classes of 50, 60, 70, 80 and 90° developmental delays)

S = number of days for preovipositional period.

Each day the total number of females remaining in each delay would oviposit an average number of eggs for their fecundity class.

$$\text{NUMEGG} = \sum_{i=1}^5 \text{NROLEF} (I) * \text{NT}$$

where I = developmental class 1 through 5,

NT = .75, 2.5, 4.0, .5 or 0, corresponding to developmental class,

NROLEF(I) = number of ovipositing onion maggot females in each developmental class (I),

NUMEGG = total number of eggs oviposited per day.

Many factors affect the placement and spatial distribution of the eggs. A static distribution (Perron 1972), where 65% of the eggs are oviposited in the soil and 35% are oviposited on the onion plant, was used because more comprehensive data were unavailable. This did not detract from the model since no migration time was assumed.

The parasitoid component involved a structure (use of delays for the various life stages) similar to the onion maggot component. The model of parasite attack was a modified version of Griffith and Holling (1969).

$$\text{ANHA} = \text{ANO} * [(1 - (1 + A * \text{TAG} * P)] / (\text{ANO} * \text{AK})] - \text{AK}$$

where ANHA = total number of hosts attacked during DT,

ANO = prey density,

A = number of attacks per unit time,

TAG = total time available for generating attacks,

P = parasitoid density,

AK = dispersion coefficient, "k" of negative binomial (parasite).

The model used the number of available hosts, along with the number of adult parasitoids, to generate a per cent parasitism.

$$PATT = ANHA / (ANO * 2.0 / SPC) * .1$$

where PATT = per cent attack by parasites,

SPC = onion plant spacing,

$$IPPO = 7.1 * PP.$$

where PP = number of parasitized pupae,

IPPO = number of female parasitoids emerging from parasitized pupae.

In the model, provisions were made for discovering individuals that were previously parasitized. The data of Salkeld (1959) suggest that *A. pallipes* can discriminate between parasitized and nonparasitized hosts. This was simulated in the model by removing the parasitized larvae from the normal flow through the larval delays. The parasitized larvae (each DT) were placed into a parallel delay. To generate parasitized larvae, the model of attack used larvae only from the unparasitized, onion maggot component. Thus, larvae are never parasitized more than once. The attack rates were applied to the intermediate rates of the larval delays. This acted as an attrition to the delay and added to the parasitized larval intermediate rates. The parasitized larval flow proceeded at a rate 20% faster (Salkeld 1959).

Results and Discussion

No independent set of data was available for validation of the model; however, the model met known features of onion maggot biology. These features included:

- 1) The onion maggot has three overlapping generations per season in Michigan.
- 2) The development of the life stages is temperature-controlled and peaks of adult emergence may be predicted through degree-day accumulations.
- 3) The maximum damage to onions usually occurs early in the season when bulbs are small.

Figure 3 (A) shows how the model adequately simulated the first two of these conditions. Given an initial population of 1000 pupae per acre, three, non-overlapping generations were simulated due to the relatively short time spent in preoviposition. The peaks of these curves represented maximum adult emergence and occurred at degree-day accumulations of 500, 2200 and 3500 for the East Lansing, Michigan, weather data of 1977. These values agree with those of Eckenrode *et al.* (1975) who reported a thermal unit accumulation of 712, 1899 and 3157 for the first, second and third broods, respectively.

The third condition was also simulated, as illustrated by plotting the per cent of onions left in the field versus the number of days in the growing season (Fig. 3B). Early in the season, damage increased as total larvae increased. Damage then tended to level off even though the larval population continued to increase. The response was due to larger bulbs, which had a greater tolerance to larval feeding.

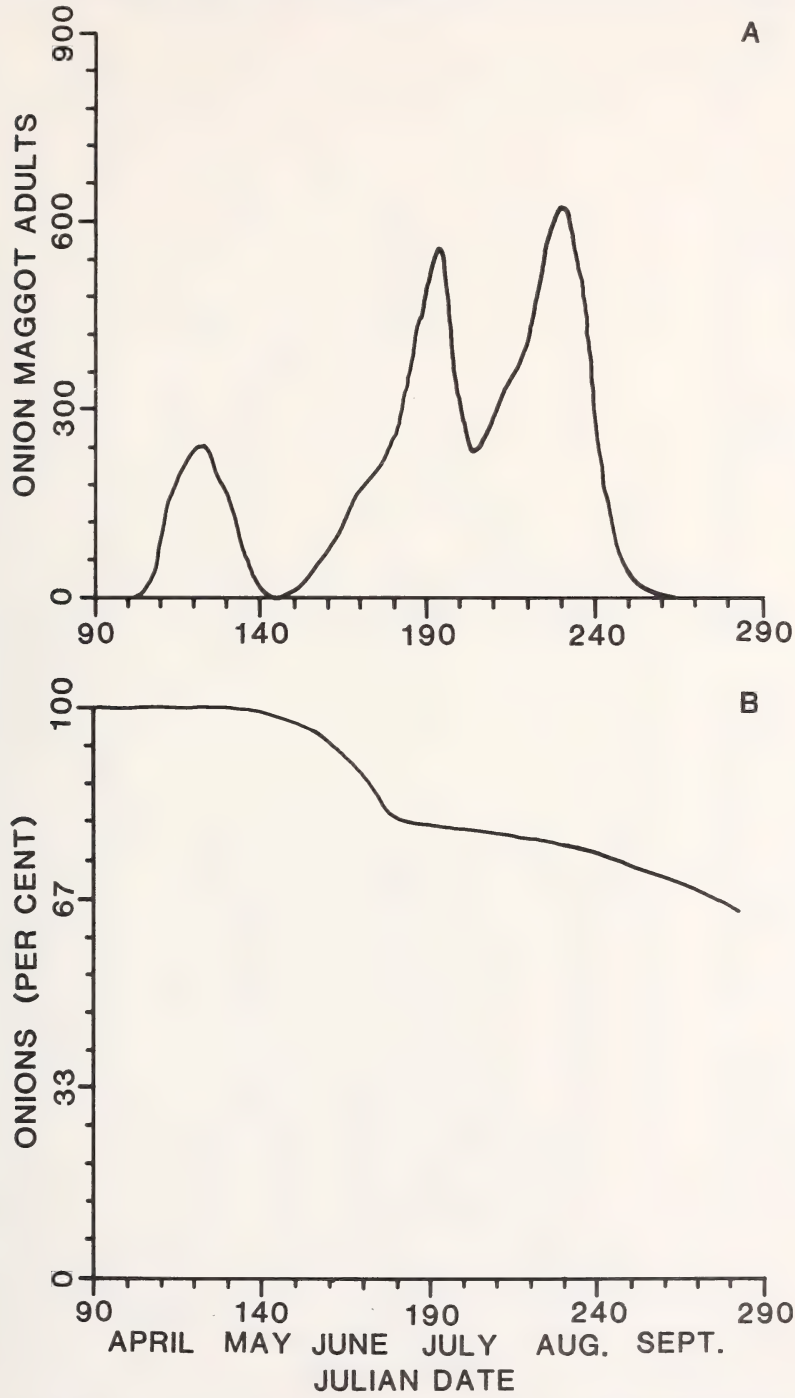


FIG. 3. Simulation with an initial overwintering population of 1000 onion maggot pupae per acre. A, number of adults in preovipositionary classes, and B, per cent of onions not damaged by maggots over time.

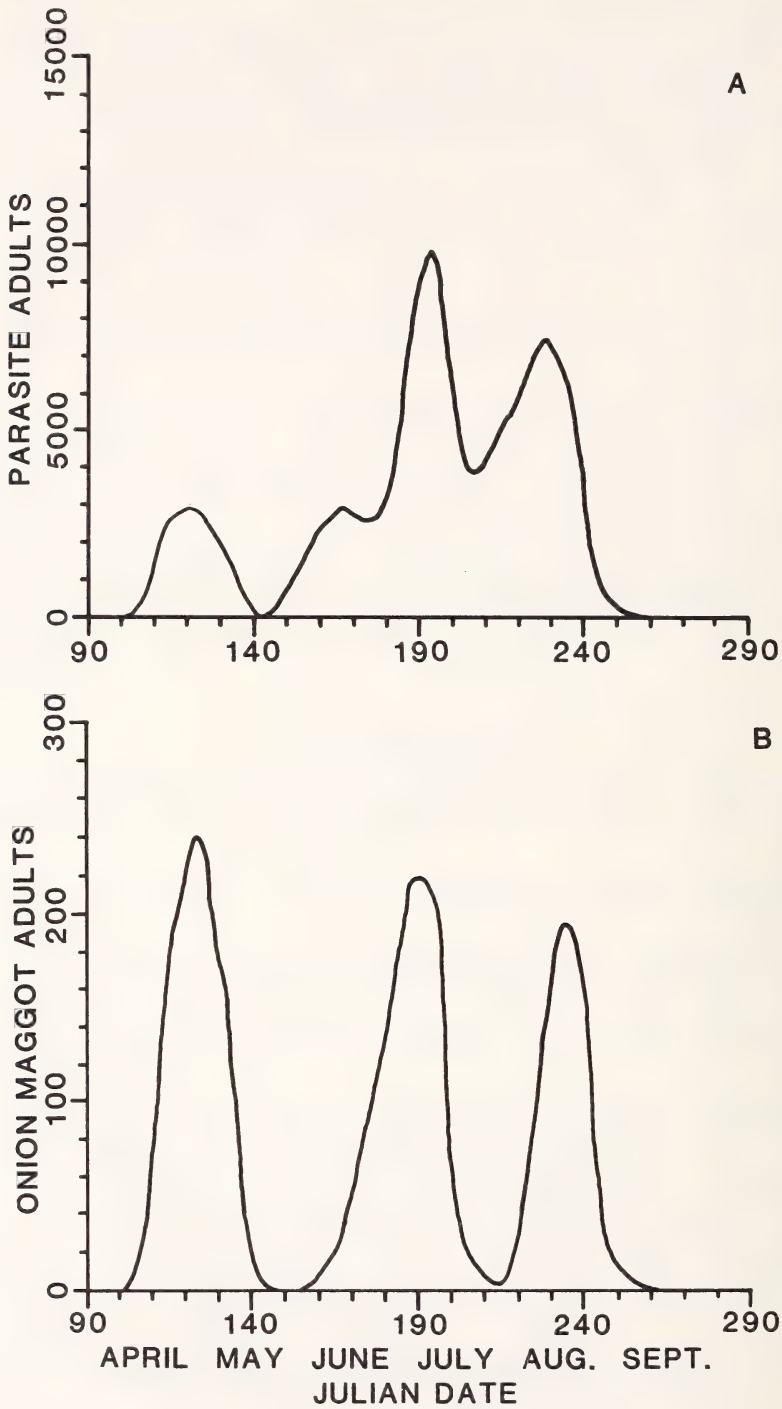


FIG. 4. Simulation with an initial overwintering population of 1500 pupae of which 500 are parasitized. A, number of adult parasitoids; and B, number of onion maggot adults in pre-ovipositionary classes.

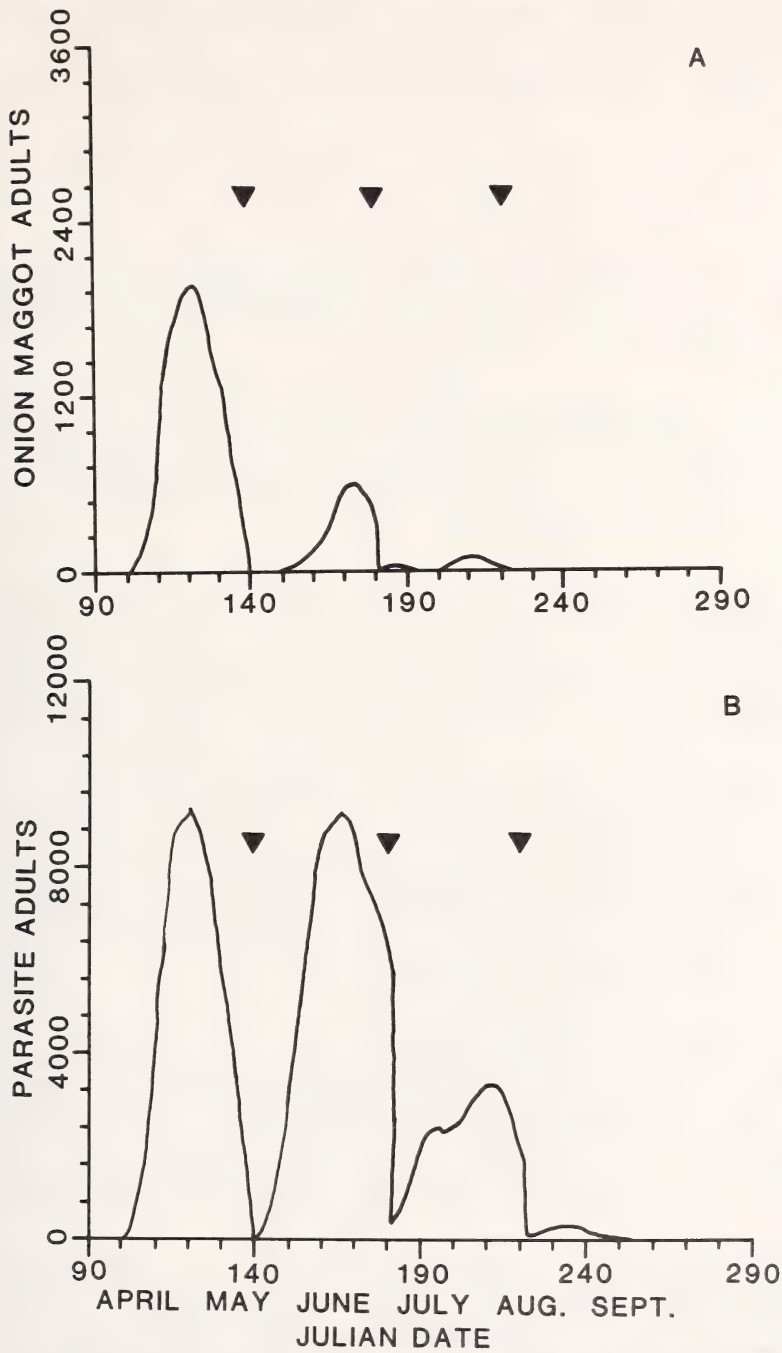


FIG. 5. Simulation with an initial overwintering population of 12,000 onion maggot pupae of which 2000 were parasitized. A foliar spray of malathion was applied at day 140, and every 40 days thereafter (▼ = spray date). A, number of onion maggot adults in preovipositionary classes; and B, number of adult parasitoids.

Given that the model simulated onion maggot development and consumption correctly, three simulations were made to analyze:

- 1) the effect of a parasitoid on the density of onion maggot and on onion yield.
- 2) the effect of foliar sprays on onion maggot, parasitoid densities and onion yield, and,
- 3) the importance of the timing of the first foliar spray.

For the first run, an initial population of 1000 pupae and 500 parasitized pupae per acre was used. There were three distinct peaks of reproducing parasite populations (Fig. 4A) that were closely synchronized with the preoviposition peaks of the previous run (Fig. 3A).

The parasitoid population decreased the second and third generation of preoviposition onion maggots, from peaks of 515 to 220 and from 610 to 200 over the previous run (Fig. 4B). The first generation was not affected. As a result of the decrease in the onion maggot population later in the season, late damage to onions was less. This simulation resulted in a net profit of \$298.00 per acre, as opposed to \$9.00 without parasitoids.

In the second analysis, a spray of malathion was applied on day 140, and every 40 days thereafter, to an initial population of 10,000 pupae and 2000 parasitized pupae per acre. Day 140 was picked for the first spray date to coincide with the end of the first preoviposition peak of the onion maggot, so that the adult population, now at its reproducing peak, would be sprayed at an optimum time. By spraying every 40 days thereafter, each successive generation of reproducing adults would also be sprayed at an optimum time. Densities of onion maggot decreased considerably (Fig. 5A). The first generation of reproducing parasitoids, however, had already reached a peak at day 140 and the malathion spray had little effect on the first generation adults (Fig. 5B). The second generation of parasitoids was reduced a little by the residual effect of the day 140 spray, but again was not greatly reduced by the next spray at day 180, since the population had already peaked. The \$172.18 net profit was low due to larval feeding early in the season. The number of parasitized, diapausing pupae, however, was high at the end of the season compared to the densities of onion maggot and could be expected to have an important effect the following year.

The third analysis investigated whether the timing of the first spray was critical to populations of the onion maggot and its parasitoid. A spray of malathion was applied on day 170, and every 40 days thereafter, to an initial population of 10,000 onion maggot pupae and 2000 parasitized pupae per acre. The first spray was applied after the build-up of reproducing onion maggots. As a result, the second generation of onion maggots was not decreased as much as it was in the previous run, and densities of onion maggot remained higher late in the season (Fig. 6A).

The reproducing population of parasitoids, however, was not reduced by the first spray until halfway through their second generation (Fig. 6B). The population remained high to the end of the season. Although the high population would reduce numbers of onion maggots the next year, the outcome for the current year was a net loss of \$1100.00 per acre.

All results (Figs. 3-6) are those of the simulations. Validation of specific runs was not possible because of the atypical nature of these simulations. Little to

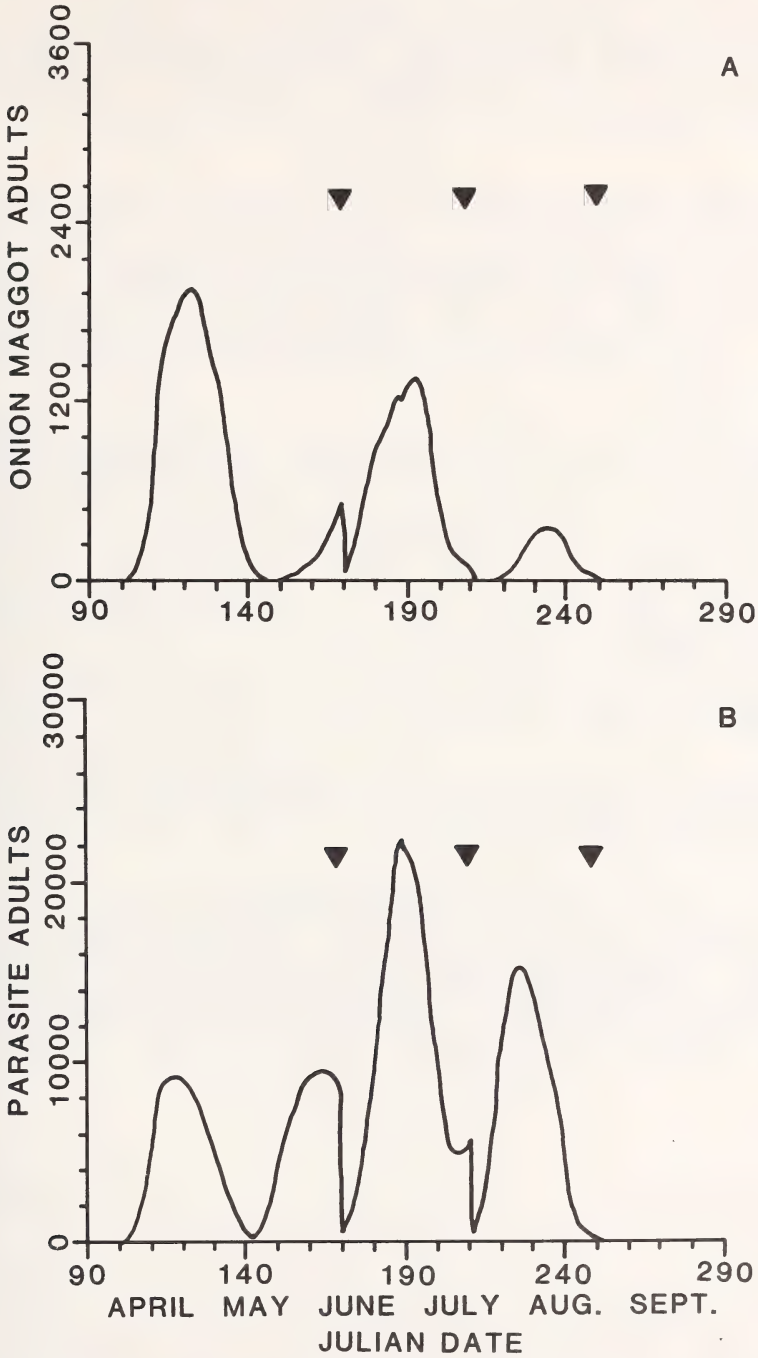


FIG. 6. Simulation with an initial overwintering population of 12,000 onion maggot pupae of which 2000 were parasitized. A foliar spray of malathion was applied at day 170, and every 40 days thereafter (▼ = spray date). A, number of adult onion maggots in preovipositionary classes; and B, the number of adult parasitoids.

no quantitative information was available about field densities of the onion maggot, its parasitoid, and the results of chemical controls. Simulation runs could only be compared to available information about onion maggot biology. Model performance was acceptable in this regard.

Conclusion

The model adequately simulated the development of the life stages of the onion maggot and was sensitive to changes in biotic and abiotic parameters. It revealed interesting information and relationships about the population dynamics of the onion maggot, the effects of carefully-timed, insecticide sprays to avoid parasitoid mortality, and the effects of onion size on damage estimates early in the season. At the same time, it presented areas where more information is needed, such as migration, damage distributions, density-dependent effects and pesticide efficiency.

The distribution of damage assumed in the model was random, although some data pointed to a clumped distribution, especially later in the season (R. Carruthers¹⁰, personal communication). Damage distribution was found to affect consumption rates, survivorship and parasitism. As a result, a damage-distribution component was essential to perfecting the model.

It was assumed that there were no density-dependent effects. No information is available on density-dependent features. However, such effects, if present, would undoubtedly influence all areas of the model.

Further work, presently in progress, on the sub-components of the onion ecosystem, will eventually lead to an overall model that can be used in pest management.

The model was coded in Fortran IV and designed specifically to be run on the Michigan State University Cyber 750 computer system. A listing of the code is available upon request from the authors.

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¹⁰ Mr. R. Carruthers, Dept. of Entomol., Mich. State Univ., E. Lansing, MI, 1978.

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TAXONOMY OF *CRICOTOPUS* SPECIES (DIPTERA: CHIRONOMIDAE) FROM SALEM CREEK, ONTARIO

by

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Abstract

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Eleven species of *Cricotopus* collected in Salem Creek, Southern Ontario are described on the basis of imagines (I), pupae (P), and larvae (L), where possible. These are: *C. annulator* Goetghebuer (I), *C. bicinctus* (Meigen) (IPL), *C. festivellus* (Kieffer) (IP), *C. infuscatus* (Malloch) (IPL), *C. politus* (Coquillett) (IPL), *C. sylvestris* (Fabricius) (IPL), *C. slossonae* Malloch (IPL), *C. triannulatus* (Macquart) (IPL), *C. trifascia* Edwards (IPL), *C. varipes* Coquillett (IPL) and *C. luciae* n. sp. (I). Three names are placed in synonymy: *C. exilis* Johannsen for *C. triannulatus* (Macquart), *C. irwini* Sublette & Sublette for *C. annulator* Goetghebuer and *C. ithacanensis* Sublette for *C. trifascia* Edwards. It is suggested that *C. politus* and *C. luciae* each be placed in new species groups. Descriptions and illustrations of the most important features are given, plus a short account of the known distribution, the status of each species and the type material of Nearctic species treated here.

Resumé

On donne la description de onze espèces de *Cricotopus* rencontrées à Salem Creek sud Ontario en utilisant autant que possible les imagos (I), les pupes (P) et les larves (L). Ce sont: *C. annulator* Goetghebuer (I), *C. bicinctus* (Meigen) (IPL), *C. festivellus* (Kieffer) (IP), *C. infuscatus* (Malloch) (IPL), *C. politus* (Coquillett) (IPL), *C. sylvestris* (Fabricius) (IPL), *C. slossonae* Malloch (IPL), *C. triannulatus* (Macquart) (IPL), *C. trifascia* Edwards (IPL), *C. varipes* Coquillett (IPL), et *C. luciae* n. sp. (I). Trois noms sont placés en synonymie: *C. exilis* Johannsen pour *C. triannulatus* (Macquart), *C. irwini* Sublette & Sublette pour *C. annulator* Goetghebuer et *C. ithacanensis* Sublette pour *C. trifascia* Edwards. On suggère de créer deux nouveaux groupes d'espèces pour *C. politus* et *C. luciae*. La description de chaque espèce est accompagnée de l'illustration des caractères importants, plus un court exposé sur la distribution connue, son statut taxonomique et enfin sur le matériel type des espèces néarctiques décrites ici.

Introduction

Hirvenoja (1973) suggested that the genus *Cricotopus* and its nearest relatives (*Acricotopus* Kieffer, *Paratrachocladus* Santos Abreu, *Paracladius* Hirvenoja and *Halocladus* Hirvenoja) form a strictly monophyletic group. Imagos of the genus *Cricotopus* are readily distinguished from other Orthoclaadiinae by the following characters: eyes hairy, dorsocentral setae short and adpressed, anterior notopleural setae usually absent, sensilla chaetica rarely absent on mid and hind legs. abdomen with interspersed white and dark segment in most species and usually with a median, white band on fore femora. The larva has a 'seta interna' on the mandible and the premandibular brush is either reduced or absent, the labral setae, SI, are bifurcate and the parlabial beard is absent. The lateral setae on abdominal segments I-VIII are usually in the form of a setal brush. When

abdominal setal brushes are absent, larvae of *Cricotopus* (*Cricotopus*) are hardly distinguishable from those of *Orthocladius* (*Orthocladius*). In the pupa, the patches of spines on the abdominal tergites are either fused or separated from each other; the frontal setae are generally present but when absent there is no patch of spines on abdominal tergites VII-VIII; the prothoracic horn is very rarely absent.

The genus has a world-wide distribution (Hirvenoja 1973). In North America it is known from the Arctic (Oliver 1962) to the southern United States (Sublette and Sublette 1971; Beck and Beck 1959). It occupies a wide variety of aquatic habitats with greatly differing water qualities (Curry 1965; Roback 1974; Beck 1977).

The aim of this paper was to provide a taxonomic basis for an ecological study on *Cricotopus* in Salem Creek, 15 km north of Waterloo, southern Ontario. A thorough revision of Nearctic species is needed but, as this would involve years of work, the scope of this study has been limited to describing the larvae, pupae and adults, whenever possible, of twelve species encountered in this stream. It is hoped that these descriptions of common southern Ontario species will form a useful reference for further, more extensive taxonomic and ecological studies on these important freshwater insects.

A full description of these species, using Hirvenoja's (1973) format, has been produced as part of a Ph.D. thesis (LeSage 1979). This included numerous measurements and counts of a number of structures, which proved to have overlapping ranges of variation between species. Examples of these are: the chaetotaxy of the head, the length of segments of the palps, the length of segments of the legs, the lateral coloration of the thorax, the chaetotaxy of the thorax, the haltere, etc. These have all been omitted from this paper but are available from the thesis.

A detailed list of collector's localities, as presently recorded in the literature is not included as most species are probably widespread in North America and some identifications are in doubt.

Historical Review of Nearctic Species

Say (1823) recognized the first Nearctic species of *Cricotopus* (as *Chironomus geminatus*) and by 1965 Sublette and Sublette catalogued 33 species for North America. Most descriptions were based on the adults, either males (Packard 1869; Coquillett 1902; Malloch 1915; Wirth 1957), females (Johannsen 1905; Malloch 1915; Walley 1928; Dendy & Sublette 1959), both sexes (Malloch 1915; Curran 1929; Roback 1957b), or adults associated with their immature stages (Johannsen 1905, 1942, 1943; Roback 1957a; Wirth 1957). Thirteen additional references referred to European literature.

Johannsen (1937) divided the genus into three groups but the four groups suggested by Roback (1957a), based on features of immatures, are defined better and represent natural assemblages. Ten years later, Sublette (1966a,b, 1967a,b, 1970) redescribed the type specimens of North American chironomids and also described two new species from the *Cricotopus* type material. Meanwhile, Saether (1967) detailed the characteristics of a larva referred to as *C. glacialis* Edw. from Ella Island, Northwest Territories. Bath & Anderson (1969) described an unnamed *Cricotopus* larva from California. Saether (1971) reared two unusual species in which the males bore female-like antennae and had projecting scuta.

An historical highpoint in *Cricotopus* taxonomy and chironomid knowledge in general was the publication of a monumental monograph on European *Crico-*

topus and related genera by Hirvenoja (1973). This work provided a solid base for future revision of the genus in other regions of the world, and contained keys, descriptions and illustrations of all known adults, males and females, as well as pupae and larvae.

The Nearctic fauna is in need of a similar revision. Meanwhile, descriptions of individual species continue to appear; the latest being that of *C. mackenziensis*, a new species closely related to *C. bicinctus*, from the Northwest Territories by Oliver (1977).

Materials and Methods

This study is based primarily on the examination of approximately 400 slide-mounted individuals, and over 15,000 specimens, preserved in alcohol, collected at Salem Creek, and from surrounding areas. The type-material was mounted in Canada balsam according to a technique used at the Biosystematics Research Institute (Roussel 1978), non-type material was dissected and mounted directly from alcohol in polyvinyl-lactophenol.

Figures were drawn with the aid of a drawing tube. Only those portions of the female genitalia which previous authors had found useful were drawn; namely, the lateral sternites IX, the coxosternapodemes, the spermathecae and the spermathecal ducts (see Saether 1977, for discussion on female genitalia). Counts and measurements were made normally on the right side of the animal and the values reported as means followed by ranges in brackets following Hirvenoja's (1973) format. Length of leg segments, wing length, and other dimensions were measured with a calibrated ocular micrometer (Soponis, 1977). Generally, ten specimens were used for counts and measurements but supplementary specimens were dissected and mounted to check on variation. Although these specimens were not included in measurements, they were sometimes employed for illustrations.

The origin of nearly all the material was Salem Creek in southern Ontario, an enriched alkaline and well oxygenated stream, running on a very hard cobble-pebble-gravel-sand substratum, encrusted by marl deposits (LeSage and Harrison 1980). Unless stated otherwise, all the specimens were collected or reared by the first author.

Terminology and Nomenclature

Terms used in the present study follow essentially those of Hirvenoja (1973) to whom the reader is referred for a complete discussion; however, the thoracic sclerites are named according to Hansen & Cook (1976). The term "sensilla chaetica" corresponds to the "*Sinneszapfen*" of Hirvenoja (1973). The following ratios are used in descriptions:

Antennal ratio = length of antennomeres 1-12/length of antennomere 13
(adult male)

Hypostomial ratio = length of hypostomium/width hypostomium (larva)
(Fig. 1)

Prothoracic horn ratio = length prothoracic horn/width prothoracic horn
(pupa)

In the adults, the abdominal tergal chaetotaxy was most reliable on tergites III-IV and therefore only the setal pattern on these tergites is reported here.

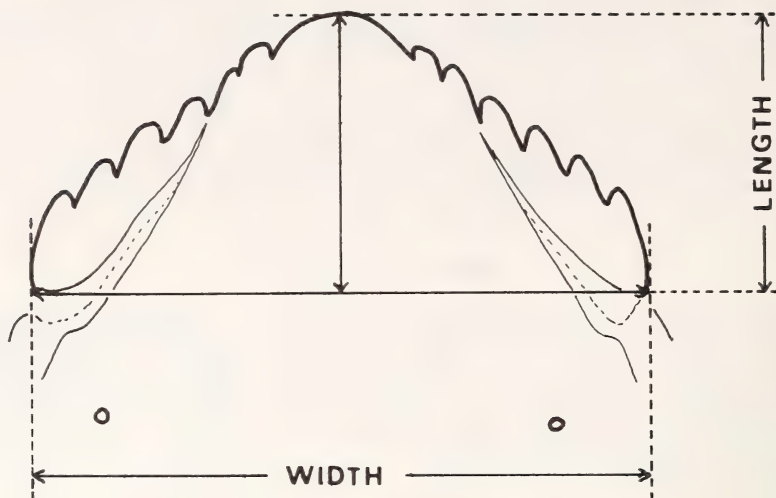


FIG. 1. Hypostomium (larva) showing derivation of hypostomium ratio. Length, from the base of 6th lateral tooth to the tip of median tooth. Width, maximum distance between the two, 6th lateral teeth.

Hirvenoja (1973) divided the genus *Cricotopus* into two subgenera: *Cricotopus* with 11 species-groups and *Isocladius* with 7 species-groups. Ten of the species we studied belong to the subgenus *Cricotopus*, only *C. sylvestris* belongs to the subgenus *Isocladius* in the *sylvestris*-group. The species are related to species groups as follows: *C. varipes*, *C. slossonae*, *C. annulator* and *C. infuscatus* in the *tremulus*-group; *C. festivellus* in the *festivellus*-group; *C. bicinctus* in the *bicinctus*-group, *C. trifascia* in the *trifascia*-group.

C. luciae and *C. politus* do not fit into any of Hirvenoja's species-groups. A revision of Nearctic *Cricotopus* would have to include two new species-groups for these and other species yet to be described completely or discovered.

All species listed here belong to the subgenus *Cricotopus* except for *C. sylvestris* which belongs to *Isocladius*.

KEYS TO *CRICOTOPUS* SPECIES FROM SALEM CREEK, SOUTHERN ONTARIO

Males

- 1—Basal lobe of the gonocoxite biramous, not directed backwards (Figs. 2, 5, 7, 8) 2
- Basal lobe of the gonocoxite uniramous, directed backwards (Figs. 10, 12, 14, 16, 18, 20), at most weakly notched (Fig. 15) 6
- 2—Tergites I-II white, the rest dark brown. Anal point usually present. Inner lobe of gonostyle not developed (Figs. 2, 4, 5) 3
- Coloration different. Anal point absent. Inner lobe of gonostyle well developed (Figs. 7, 8) 4
- 3—All fore tarsi dark brown (Fig. 2f).....*C. varipes* Coquillett
- Fore tarsus 1 and basal half of tarsus 2 light (Fig. 5f) *C. slossonae* Malloch

- 4—Tergites III-IV white at least on posterior half (Fig. 8i)
.....*C. triannulatus* (Macquart)
—Tergites III-IV brown (Figs. 7, 10) 5
- 5—Small species, 2.6 (2.3-3.2) mm long. White ring on fore tibia. Tergal chaetotaxy reduced (Fig. 7a). Anterior lobule of basal lobe of gonocoxite much larger than posterior lobule (Fig. 7f).....*C. annulator* (Goetghebuer)
—Medium sized species 3.1 (2.9-3.6) mm long. No white ring on fore tibia. Anterior lobule of basal lobe of gonocoxite about the same size or smaller than the posterior lobule (Fig. 10d,e).....*C. infuscatus* (Malloch)
- 6—Tergites brown, unicolored (Figs. 12, 14) 7
—Tergites bicolored, either white or brown (Figs. 15, 16, 18, 20)..... 8
- 7—Abdomen shining green. Hypopygium as in figure 12g
.....*C. politus* (Coquillett)
—Abdomen dark brown to black. Hypopygium as in figure 14i
.....*C. luciae* Lesage & Harrison
- 8—Basal lobe of gonocoxite absent (Fig. 18e).....*C. trifascia* Edwards
—Basal lobe of gonocoxite well developed (Figs. 15, 16, 20)..... 9
- 9—Tergite VII completely or partly white (Fig. 20f). Median tergal setae much stronger than lateral setae (Fig. 20a) *C. sylvestris* (Fabricius)
—Tergite VII brown. Median and lateral setae of equal size (Figs. 15a, 16a) 10
- 10—Tergite IV brown anteriorly (Fig. 15i). Median tergal setae uniserial (Fig. 15a). Basal lobe of gonocoxite weakly notched (Fig. 15e, d, h) not elongated *C. festivellus* (Kieffer)
—Tergite IV completely white (Fig. 16h). Median tergal setae biserial (Fig. 16a). Basal lobe of gonocoxite elongated, not notched (Fig. 16e, g)
.....*C. bicinctus* (Meigen)

Females

- 1—Spermathecal ducts straight (Figs. 16, 18) 2
—Spermathecal ducts looped or S-shaped (Figs. 2, 5, 7, 8, 10, 12, 15, 20) 3
- 2—Small species less than 3 mm long. Wing vein R_{4+5} with less than 4 setae (Fig. 16c). Less than 10 sensilla chaetica on mid hind legs
.....*C. bicinctus* (Meigen)
—Large species more than 3 mm long. Wing vein R_{4+5} with more than 5 setae (Fig. 18a). More than 30 sensilla chaetica on mid and hind legs
.....*C. trifascia* Edwards
- 3—Abdominal tergites with uniform coloration, usually brown (Figs. 7, 10, 12, 14) 4
—Abdominal tergites bicolored, either entirely or partly white or brown (Figs. 2, 7, 8, 15, 20) 7
- 4—Spermathecae pear-shaped (Fig. 12f). Two transverse rows of setae present on tergites (Figs. 12a) *C. politus* (Coquillett)
—Spermathecae roundish. One transverse row of setae present on tergites (Figs. 7, 10, 14) 5
- 5—Wing, squama with more than 13 setae, vein R with more than 12 setae (Fig. 14c). Spermathecae less than 80 μ m diameter (Fig. 14g)
.....*C. luciae* LeSage & Harrison
—Wing, squama with less than 13 setae, vein R with less than 12 setae (Figs. 7c, 10c) spermathecae more than 80 μ m diameter (Figs. 7g, 10g) 6

- 6—Small species usually less than 3 mm long. Thoracic mesonotal bands not contrasting on the dark brown ground color. Antennal preapical setae more than 210 μ m. Wing vein R_1 without setae (Fig. 7c)
.....*C. annulator*, Goetghebuer (dark specimens)
—Medium sized species usually more than 3 mm long. Thoracic mesonotal bands sharply contrasting on the yellowish ground color. Antennal pre-apical setae less than 210 μ m. Wing vein R_1 with 3-8 setae (Fig. 10c)
.....*C. infuscatus* (Malloch)
- 7—Tergites I-II white (Figs. 2, 5, 7) or paler than others (Fig. 7d)..... 8
—Coloration different 10
- 8—Tergites I-II faintly paler (Fig. 7d). Paratergal setae absent
.....*C. annulator* Goetghebuer (light color specimens)
—Tergites I-II white. Paratergal setae present (Figs. 2, 5)..... 9
- 9—Fore tarsi all dark brown *C. varipes* Coquillett
—Basal half of fore tarsus 1 light *C. n. sp. ?*
—Fore tarsus 1 and basal half of tarsus 2 light.....*C. slossonae* (Malloch)
- 10—Tergites I, IV-V white (Fig. 8i). Genitalia, figure 8g
.....*C. triannulatus* (Macquart)
—Tergites I, V-VI white (Fig. 15i). Genitalia, figure 15g
.....*C. festivellus* (Kieffer)
—Tergites I, IV-VII white (Fig. 20f). Genitalia, figure 20e
.....*C. sylvestris* (Fabricius)

Pupae

- 1—Pronotal horn cylindrical and bare; (Fig. 21c); Tergites II-IV wholly covered by spicules (Fig. 21a).....*C. sylvestris* (Fabricius)
—Pronotal horn acute (Figs. 3, 6, 9, 11, 13, 17, 19, and Hirvenoja 1973, Figs. 122, 137), usually covered with spicules apically, with spicules on tergites II-IV grouped in patches 2
- 2—Inner anal seta much smaller than outer anal seta (Fig. 19b)
.....*C. trifascia* Edwards
—Inner anal seta equal in size to other setae (Figs. 3, 6, 9, 11, 13, 17, and Hirvenoja 1973, Figs. 122, 137) 3
- 3—Frontal setae present 4
—Frontal setae absent..... 7
- 4—Anterior and mid patches of spines fused together on tergites III-VI (cf. Hirvenoja 1973, Fig. 137) *C. festivellus* (Kieffer)
—Anterior and mid patches of spines well separated on tergites III-VI (Figs. 3, 6, 9, 11, 13, 17) and Hirvenoja 1973, Fig. 122)..... 5
- 5—With rough granulation along the eclosion line (Fig. 17c)
.....*C. bicinctus* (Meigen)
—Almost smooth along the eclosion line 6
- 6—Smaller, 3.7 (2.5-4.2) mm long. Anterior patches of spines on tergites III-VI reniform, about twice as wide as long (Fig. 9a)
.....*C. triannulatus* (Macquart)
—Larger 4.7 (3.6-4.9) mm long. Anterior patches of spines on tergites III-VI transverse, about three times as wide as long (Fig. 11a)
.....*C. infuscatus* (Malloch)

- 7—With a patch of spines in front of rows of recurved spines on tergite II (Fig. 13a) *C. politus* (Coquillett)
- Without a patch of spines in front of rows of recurved spines on tergite II (Figs. 3, 6 and in Hirvenoja 1973, Fig. 122) 8
- 8—Four lateral setae on tergites VIII (Fig. 6a) *C. slossonae* Malloch
- Five lateral setae on tergite VIII (Fig. 3a) *C. varipes* Coquillett

Larvae

- 1—Premandible bidentate (Fig. 21f). Hair tufts on abdomen very long (Fig. 21g) more than 275 μm *C. sylvestris* (Fabricius)
- Premandible simple (Figs. 3, 6, 9, 11, 17, 18). Hair tufts on abdomen shorter, less than 200 μm 2
- 2—Median tooth of hypostomium large about three times as broad as the first lateral tooth (Figs. 12c, 17d, 19f) 3
- Median tooth of hypostomium moderately large usually less than 2.5 times as broad as the first lateral tooth (Figs. 3, 6, 9, 11) 5
- 3—Mandible serrate on the inner edge (Fig. 12f) *C. bicinctus* (Meigen)
- Mandible smooth on the inner edge (Figs. 17, 19) 4
- 4—First and second lateral teeth of hypostomium very small and almost fused with median teeth (Figs. 19f)..... *C. trifascia* Edwards
- First and second lateral teeth equal in size to other lateral teeth, not fused with median tooth (Figs. 12c) *C. politus* (Coquillett)
- 5—Outer edge of the mandible smooth (Figs. 3i, 6h) *C. varipes* Coquillett, *C. slossonae* Malloch
- Outer edge of mandible crenulate (Figs. 9g, 11h) 6
- 6—Basal portion of mandible brownish. Hypostomial ratio usually smaller, 0.50-0.61 (Fig. 11h) *C. infuscatus* (Malloch)
- Basal portion of mandible light. Hypostomial ratio usually larger, 0.52-0.65 (Fig. 9h) *C. triannulatus* (Macquart)

***Cricotopus (Cricotopus) varipes* Coquillett**

Cricotopus varipes Coquillett, 1902:93 (original description, male).

Cricotopus varipes Coquillett Johannsen, 1905:256 (description of adults, immature stages); Johannsen in Johannsen & Townes, 1952:18 (in key, adults) Sublette, 1966b:591 (redescription of male); Sublette, 1967:560 (supplemental description of male).

MALE (Fig. 2).

Length. 3.1 (2.7-3.5) mm; thorax 0.9 (0.8-1.1) mm; abdomen 2.1 (1.9-2.4) mm.

Thorax. Mesonotal bands dark brown not contrasting with the dark-brown, ground colour of thorax. All thoracic sclerites dark brown.

Wings. With a brownish tint. Length 1873 (1515-2121) μm , width 572 (505-646) μm . Setae: first axillary sclerite with one seta; remigium 1.1 (1-2); squama 7.4 (5-10); vein R 6.4 (5-8), proximal; R_1 0; R_{4+5} 0. Anal lobe weakly produced.

Legs. Fore tibia with a white ring, basal dark brown portion about $\frac{1}{4}$ - $\frac{1}{3}$ the size of apical brown portion; mid and hind tibiae with a more or less distinct

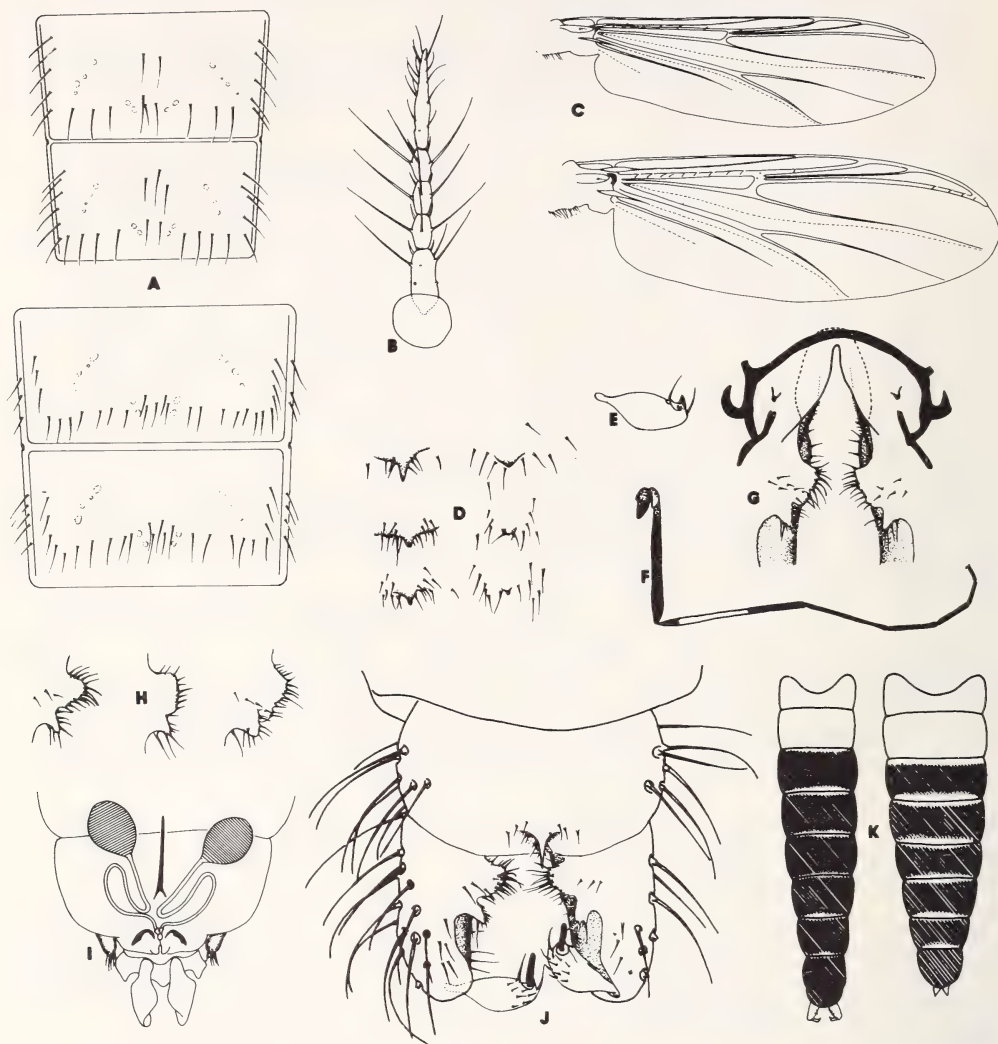


FIG. 2. *Cricotopus varipes* Coquillett, imagines. A, chaetotaxy on abdominal tergites III-IV of the male (upper), and the female (lower). B, antenna, female. C, wing, male (upper), female (lower). D, anal point, variation. E, male gonostylus, apical spine not shown. F, fore leg, coloration. G, male hypopygium, ventral view. H, basal lobe of gonocoxite, variation. I, female genitalia, ventral view (ventral lobe of gonapophysis IX not shown here and in the next figures). J, male hypopygium, dorsal view. K, abdominal coloration male (left), female (right).

yellowish ring. Fore tarsi all dark brown, mid and hind tarsi brownish to brown. Sensilla chaetica 13.0 (11-15), present only on 1/5-2/5 of hind legs.

Abdomen. Abdominal tergites I-II white; III-VII dark brown with narrow light band on anterior and posterior margins, VIII dark brown. Chaetotaxy reduced on tergites III-IV; median setae biserial; lateral setae uniserial on each side of tergites and also forming a transverse row of setae on posterior portion of tergites. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	5.4 (4-7)	9.8 (8-13)
Tergite IV	6.2 (4-8)	10.2 (8-13)

Hypopygium. White. Length of gonocoxite 196 (174-217) μm , length of gonostylus 64 (52-75) μm . Anal point triangular, long, sharp 13.3 (9-20) μm and bearing 1-3 setae on each side. Basal lobe biramous, anterior lobe larger, directed mediad or weakly cephalad, more or less apically rounded, covered by robust setae, posterior lobe triangular, smaller directed caudad and bearing rather robust macrotrichia. Gonostylus with a weakly developed inner edge but dark brown and pointed apically, and bearing a long, apical spine (14-20) μm .

FEMALE (Fig. 2)

Length 3.0 (2.7-3.5) mm; thorax 1.0 (0.9-1.2) mm; abdomen 2.0 (1.7-2.3) mm.

Antenna. Preapical seta present 67 (61-75) μm .

Thorax. Coloration as in the male.

Wings. With a brownish tint. Length 2141 (1899-2404) μm ; width 769 (707-848) μm . Setae: first axillary sclerite with one seta; remigium 1.1 (1-2); squama 10.2 (7-16); vein R 11.2 (8-14) all along; R_1 1.0 (0-2) proximal; R_{4+5} 4.1 (2-5) distal. Anal lobe obtuse.

Legs. Coloration as in the male. On basal 1/3-3/5 of mid leg, 26.6 (22-31) sensilla chaetica and 24.1 (21-26) on basal 5/12 of hind leg.

Abdomen. Coloration as in the male. In dark specimens, sternites III-VII with a grey-blue tint and brown infuscation. Chaetotaxy reduced on abdominal segments III and IV; median setae generally concentrated in group between posterior muscle marks; lateral setae uniserial on each side of tergites and forming a transverse row of setae on posterior 1/3; paratergal setae present. Tergal chaetotaxy:

	median setae	lateral setae	paratergal setae
Tergite III	4.6 (2-7)	8.8 (6-11)	2.6 (1-5)
Tergite IV	4.9 (2-7)	8.1 (6-12)	3.7 (2-7)

Genitalia. Cerci white. Spermathecae dark brown, roundish 92 (78-113) μm long, 73 (61-78) μm wide. Spermathecal ducts S-shaped. Lateral sternites of abdominal segment IX moderately developed.

PUPA (Fig. 3)

Colour: exuvia brown, somewhat paler on tergites I, VII and VIII. Length of exuvia 4.1 (4.1-4.3) mm, cephalothorax 2.9 (2.8-2.9), abdomen 1.3 (1.2-1.4).

Cephalothorax. Anterior part of notum granular in a very narrow band along the eclosion line. Pronotal horn, pointed, translucent, covered by spinules on apical

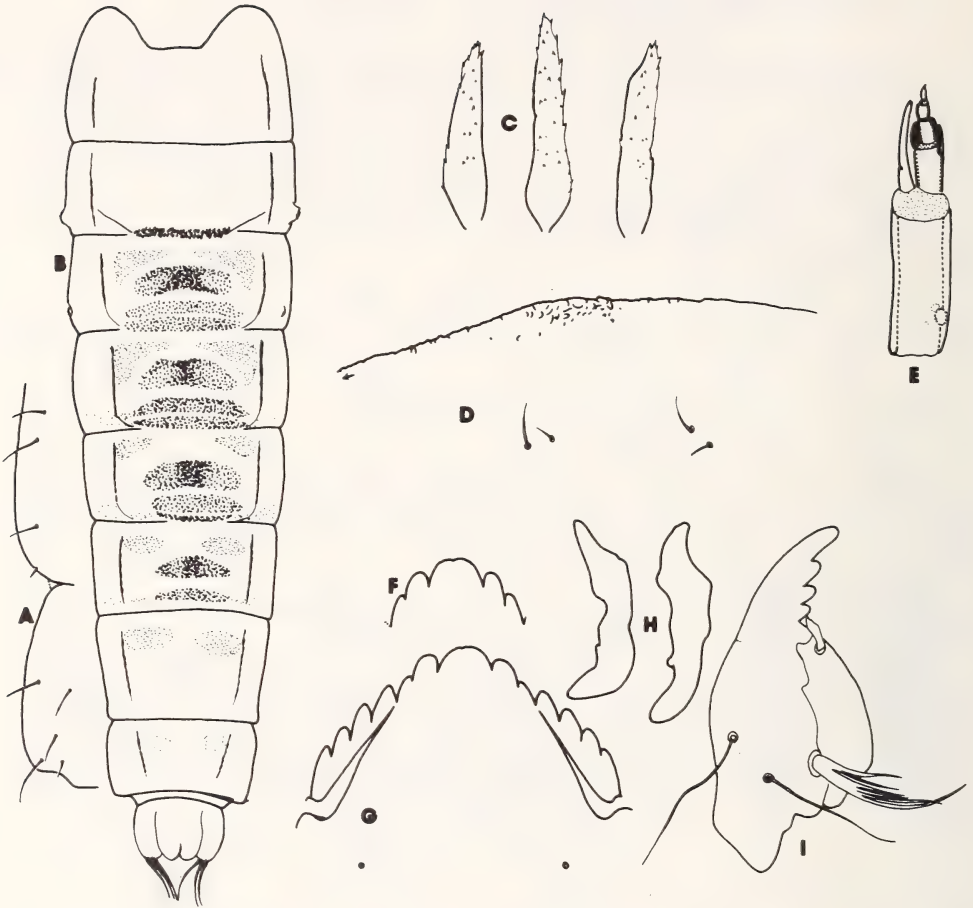


FIG. 3. *Cricotopus varipes* Coquillett, pupa A-D, larva E-I. A, lateral setae on abdominal segment IV. B, ornamentation of pupal exuvia, dorsal view. C, prothoracic horn, variation. D, ornamentation along eclosion line and dorsocentral setae. E, antenna. F, mid and first two, lateral teeth of hypostomium, variation. G, hypostomium, ventral view. H, premandible, variation. I, mandible.

$\frac{2}{3}$, 103 (73-116) μm long, 18 (16-20) μm wide. Prothoracic horn ratio 5.56 (4.57-6.80). Frontal tubercle and frontal setae absent.

Abdomen. Length of longest anal seta 168 (148-174) μm . Pedes spurii B large on abdominal segment II, small on segment III. Setae present on abdominal segments I-VIII:

	I	II	III	IV	V	VI	VII	VIII
dorsals	4	4-5	4-5	5	5	5	4-5	1
laterals	1	2	3	3	5	5	5	5
ventrals	0	3-4	3-4	4	4	4	4	1

Tergites: I bare; II sometimes with a very small median spine patch in front of the transverse patch of 85 (76-103) recurved spines, biserial; III-V with three patches of spines, one anterior, reniform patch widely separate from the median patch which is elongated, transverse and narrowly separated from the posterior, transverse, spine patch, and with a small, shagreen patch anteriorly on each side; VI with two, distinctly divided in three parts, one small patch of shagreen on each side anteriorly; VII-VIII with 2 patches of shagreen on basal third.

LARVA (Fig. 3)

Fourth-instar larva (exuvia) 4.8 (4.0-5.3) mm long. Head capsule brownish somewhat darker posteriorly and laterally.

Antenna 69 (63-73) μm long, 0.49 (0.47-0.53) as long as mandible, 5.61 (5.27-5.83) times as long as wide. Lauterborn's organs large, antennal blade extending to or sometimes beyond the apex of antennomere 4, accessory seta extending to the basal third of antennomere 3 and sensory seta to apex of antennomere 3 or base of 4. Antennal ratio 0.56 (0.52-0.62). Labral setae SI bifurcated. Epipharynx with four chaetulae laterales and two chaetulae basales; pecten with three slender setae.

Premandible simple. Distal part of mandible dark brown to black with smooth inner margin and outer edge or sometimes with very weak indistinct crenulations on outer edge.

Hypostomium 125 (109-134) μm wide, 75 (66-80) μm long. Hypostomial ratio 0.60 (0.58-0.61). Median tooth and the first two lateral teeth more or less distinctly paler than other lateral teeth. Median tooth convex, first two lateral teeth partly fused together, the second about half the size of the first. Lateral teeth 3-6 slightly and regularly decreasing in size.

Anal gills sausage-shaped tapering towards apex. Claws on anterior prolegs brown, small and very numerous, somewhat darker than the large posterior claws on posterior pseudopods. Lateral hair tufts on abdominal segments I-VII well developed, 114 (68-136) μm long.

Remarks. The abdominal tergites I-II white and the fore tarsi all dark, readily distinguish the adults of *Cricotopus varipes* from others. The male characters vary considerably in this species; the anal point was either absent in two specimens, weakly developed in a few, but usually quite robust; the basal lobe of the gonocoxite has usually the anterior portion wider than long and angular but it varied also from a lobe resembling that illustrated for *C. tristis* (Hirvenoja 1973) to that of the holotype male (Sublette 1966b). The presence of paratergal setae on the abdomen of females is an additional character shared only by females of *C.*

slossonae having, however, light fore tarsi. Superficially, *C. varipes* resembles the European *C. tristis* but the male and female genitalia are different.

The general ornamentation and the absence of frontal setae distinguished the pupa from others. On specimens examined, the presence of five lateral setae on the abdominal segment VIII was the only reliable character found for the separation of *C. varipes* from *C. slossonae* which bears four setae on this segment.

The shape of the hypostomium and the smooth, outer edge of the mandible separate the larva of *C. varipes* from all others except *C. slossonae*. No features could be found to separate these two species. However, several important characters found on other parts of the body were not visible on specimens examined (four exuvia).

C. varipes is closely related to *C. slossonae*. The two species are similar in the colour of tarsi in the adults and by the presence or absence of one tiny seta in the pupae. Nevertheless, the colour of the tarsi in the adults revealed a third "form" which has only the fore tarsus 2 light (Fig. 4). This colour pattern is intermediate between the completely dark fore tarsus in *C. varipes* and the light fore tarsus 2 and partly light fore tarsus 3 of *C. slossonae*. An ecological study of these three "forms" (LeSage & Harrison 1980, n.sp?) suggests that they might be three different species. The ovipositing females could be readily separated into three groups according to the leg coloration. Only pure swarms of *C. varipes* males having distinct dark tarsi were collected. Finally, in the spring, there was succession in the emergence of these forms, *C. varipes* emerging first, followed by the possible new species and later by *C. slossonae*. This succession occurred in reverse in the fall. However, it seems appropriate for the moment to preserve the name of *C. varipes* and *C. slossonae* as valid species but not to create a new name for the intermediate form since the ecological evidence is only partial and the immature stages of this third form are still unknown.



FIG. 4. *Cricetopus* n.sp.?. Fore leg, coloration.

Distribution. Reported from FLORIDA (Beck & Beck 1959, Sublette & Sublette, 1965) to NORTHWEST TERRITORIES (Rosenberg & Wiens 1976).

Material examined. Holotype male, Great Falls, Maryland, June 5, H. S. Barber. In the U.S. National Museum, Washington, type No. 6175. On slide: ONTARIO, Elmira, Salem Creek, 7 ♂♂ 21-31.V.76, 19 ♂♂ 1.V.77-4.XI.77, 2 ♂♂ 18-25.V.78, 14 ♀♀ 21-31.V.76, 17 ♀♀ 15.V.77-19.X.77. Associated larva-pupa-adult: Elmira, Salem Creek, 1.V.1978 (1 ♂), 11.V.78 (1 ♂), 29.V.78 (1 ♀),

31.V.78 (2 ♀ ♀), 2.VI.78 (1 intersex). In alcohol: Elmira, Salem Creek, 550 ♂ ♂, 675 ♀ ♀ from May, 1976 to November, 1978.

***Cricotopus (Cricotopus) slossonae* Malloch**

Cricotopus slossonae Malloch, 1915:506 (original description, female).

Cricotopus slossonae Malloch, Walley, 1928 (key, adults): Johannsen in Johannsen & Townes, 1952:18 (key, adults): Roback, 1957a: 71 (description, key, larva, pupa): Sublette, 1970:60 (redescription, female).

C. (C.) slossonae Malloch, Saether, 1977:116 (illustration, female genitalia).

Orthocladius sp. D. Malloch, 1915:531, *fide* Roback, 1957a: 71 (description, pupa).

MALE (Fig. 5)

Length 3.1 (2.4-3.8) mm; thorax 0.9 (0.7-1.1) mm; abdomen 2.1 (1.7-2.7) mm.

Thorax. Mesonotal bands dark brown not contrasting with the dark brown ground colour of thorax. All thoracic sclerites dark brown.

Wings. With a brownish tint. Length 1802 (1414-2121) μm , width 519 (424-626) μm . Setae: first axillary sclerite with one seta; remigium 1.1 (1-2); squama 7.2 (4-11); vein R 5.2 (3-8) proximal; R_1 0; R_{4+5} 0. Anal lobe obtuse.

Legs. White ring on fore tibia, apical dark portion about 5 times longer than basal dark portion, mid and hind tibiae with more or less distinct large yellowish ring. Fore tarsi 1, 4-5 dark brown; fore tarsi 2 and basal $\frac{2}{3}$ of fore tarsi 3 whitish. Mid and hind tarsi yellowish or pale brown. 11.0 (8-14) sensilla chaetica only on basal $\frac{1}{4}$ of hind legs.

Abdomen. Tergites I-II white, III-VII dark brown and generally with distinct pale narrow band along anterior and posterior margins, VIII dark brown. In dark specimens sternites III-VII with a grey-blue tint and brown infuscation. Chaetotaxy reduced on tergites III-IV; median setae generally biserial; lateral setae uniserial on each side of the abdomen and also forming a transverse row of setae on the posterior portion of tergites. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	5.3 (3-7)	10.6 (7-18)
Tergite IV	6.4 (4-8)	10.1 (6-15)

Hypopygium. White. Length of gonocoxite 189 (165-217) μm , gonostylus length 61 (52-78) μm . Anal point small to robust, transparent with setae at its base. Basal lobe biramous: anterior lobe apically roundish to angular, directed mediad and bearing robust setae, posterior lobe triangular, directed caudad and bearing weaker setae. However shape very variable. Dististyle dark brown apically and pointed with apical spine 20 μm long and inner edge weakly developed.

FEMALE (Fig. 5)

Length 3.0 (2.6-3.7) μm ; thorax 1.0 (0.9-1.3) mm; abdomen 2.0 (1.7-2.4) mm.

Antenna. Preapical seta present 67 (59-70) μm .



FIG. 5. *Cricotopus slossonae* Malloch, imagines. A, chaetotaxy on abdominal tergites III-IV of the male (upper), and the female (lower). B, antenna, female. C, wing, male (upper), female (lower). D, male hypopygium, ventral view. E, anal point, variation. F, fore leg, coloration. G, male gonostylus, variation. H, basal lobe of gonocoxite, variation. I, female genitalia, ventral view. J, male hypopygium, dorsal view. K, abdominal coloration, male (left), female (right).

Thorax. Coloration as in the male.

Wings. With a brownish tint. Length 1925 (1697-2101) μm , width 721 (626-848) μm . Setae: first axillary sclerite with one seta, remigium 0.1 (1-2); squama 11.0 (8-15); vein R 11.6 (9-18); R_1 0.9 (0-3); R_{4+5} 2.0 (1-5). Anal lobe obtuse, not produced.

Legs. Coloration as in the male. 33.8 (29-40) sensilla chaetica on basal $\frac{5}{8}$ - $\frac{2}{3}$ mid tarsi 1 and 23.2 (18-27) on basal $\frac{1}{3}$ hind tarsi 1.

Abdomen. Coloration as in the male. In dark specimens, sternites III-VII with a grey-blue tint and brown infuscation. Chaetotaxy reduced on tergites III-IV; median setae generally grouped between posterior muscle marks; lateral setae generally uniserial on each side of tergites and also forming a transverse row of setae on posterior portion of tergites. Tergal chaetotaxy:

	median setae	lateral setae	paratergal setae
Tergite III	3.8 (2-6)	9.4 (8-14)	2.4 (1-5)
Tergite IV	4.4 (2-6)	8.5 (6-10)	4.3 (2-8)

Genitalia. Cerci white. Spermathecae dark brown, roundish, 93 (78-102) μm long, 76 (64-80) μm wide. Spermathecal ducts S-shaped. Lateral sternites of abdominal segment IX moderately developed.

PUPA (Fig. 6)

Colour: exuvia brown, somewhat paler on I, VII and VIII. Length of the exuvia (mm) 3.8 (3.1-4.2); cephalothorax 2.6 (2.1-2.9); abdomen 1.1 (1.0-1.2).

Cephalothorax. Anterior part of notum granular in a very narrow band along the eclosion line. Pronotal horn, pointed, translucent, covered by spinules on apical $\frac{2}{3}$, 106 (91-127) μm long, 20 (18-23) μm wide. Prothoracic horn ratio 5.35 (4.30-6.22). Frontal tubercle and frontal setae absent.

Abdomen. Anal lobe length 250 (243-261) μm longest anal setae length 165 (157-174) μm . Pedes spurii B large on abdominal segment II, small on segment III. Setae present on abdominal segments I-VIII:

	I	II	III	IV	V	VI	VII	VIII
dorsals	4	4-5	4-5	5	5	5	4-5	1
laterals	1	2	3	3	5	5	5	4
ventrals	0	3-4	3-4	4	4	4	4	1

Tergites: I bare; I with sometimes very small median spine patch in front of the transverse patch of 78 (68-92) μm recurved spines, biserial; III-V with three spine patches, one anterior reniform widely separated from the median patch which is elongated and transverse and close to the posterior transverse spine patch, and with small shagreen patches anteriorly on each side; VI with two median spine patches; posterior patch transverse more or less distinctly divided in three parts; one small patch of shagreen on each side anteriorly; VII-VIII with 2 patches of shagreen on basal third.

LARVA (Fig. 6)

Fourth instar larvae 4.4 (3.5-5.1) mm long (exuvia). Head capsule brownish somewhat darker posteriorly and laterally.

Antenna 72 (62-79) μm long, 0.49 (0.44-0.56) as long as mandible, 5.24

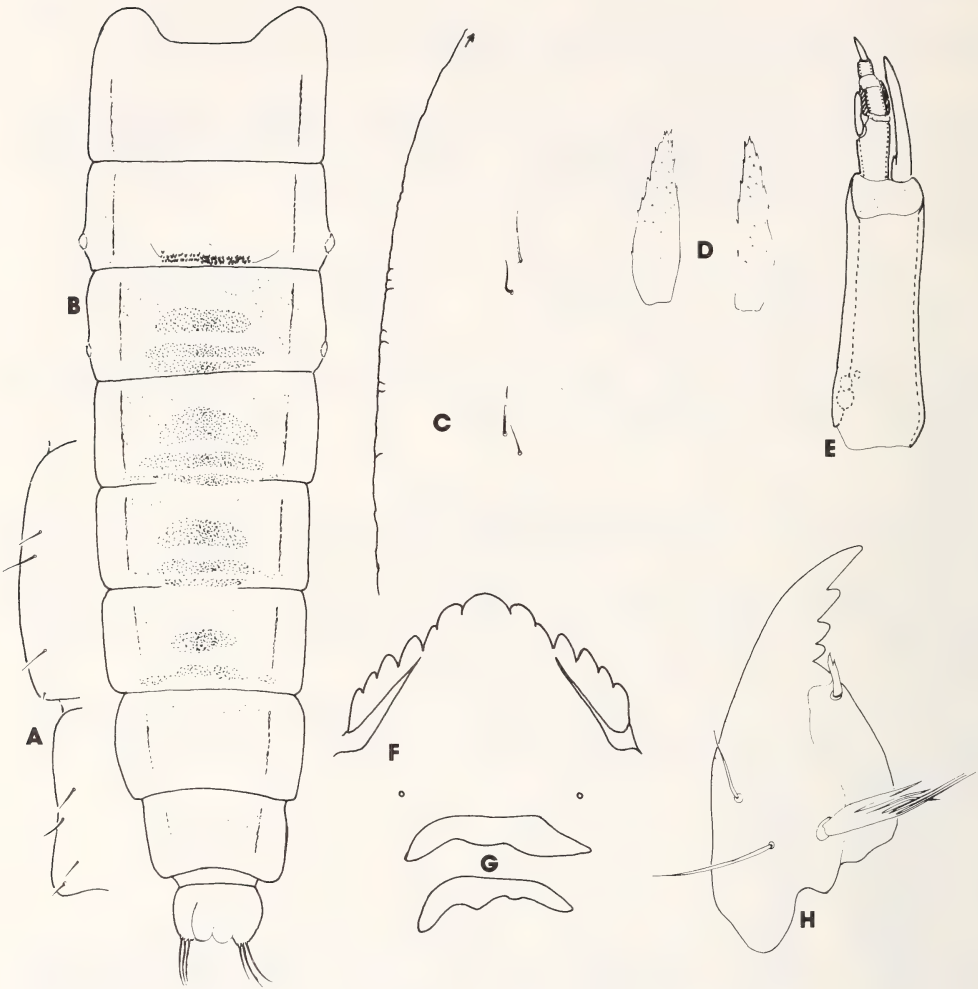


FIG. 6. *Cricotopus slossonae* Malloch, pupa A-D, larva E-H. A, lateral setae on abdominal segment IV. B, ornamentation of pupal exuvia, dorsal view. C, ornamentation along eclosion line and dorsocentral setae. D, prothoracic horn, variation. E, antenna. F, hypostomium, ventral view. G, premandible, variation. H, mandible.

(4.29-6.00) times as long as wide. Lauterborn's organs large, antennal blade extending to or sometimes beyond the apex of antennomere 4, accessory seta to the basal $\frac{1}{3}$ of antennomere 3, and sensory seta to apex of antennomere 3, or base of 4. Antennal ratio 0.50 (0.38-0.58). Labral setae SI bifurcated. Epipharynx with four chaetae laterales and two chaetae basales; pecten with three slender setae.

Premandible simple. Distal part of the mandible dark brown to black with smooth inner margin and outer edge, or sometimes with very weak indistinct crenulations on outer edge.

Hypostomium 126 (118-136) μm wide, 75 (68-82) μm long. Hypostomial ratio 0.60 (0.58-0.61). Median tooth and the first two, lateral teeth more or less distinctly paler than other lateral teeth. Median tooth convex, first two, lateral teeth partly fused together, the second about half the size of the first; lateral teeth 3-6 slightly and regularly decreasing in size.

Anal gills, sausage-shaped tapering towards apex. Claws on anterior prolegs brown, small and very numerous, somewhat darker than the large posterior claws on posterior pseudopods. Lateral hair tufts on abdominal segments I-VI well developed 128 (102-148) μm .

Remarks: Adults of *Cricotopus slossonae* are readily recognizable by their light abdominal tergites I-II and their light fore tarsi 2 and partly light fore tarsi 3. The type specimen of this species, a female, has these typical characters as originally described. Reared males and females bearing this colour pattern were placed in the same species and this association was furthermore corroborated by the similar immatures of both sexes. The pupa differs from others by its ornamentation and the absence of frontal setae, but could be separated from *C. varipes* only on the basis of four setae present on abdominal segment VIII whereas there were five in *C. varipes*. As mentioned above, larvae of these two species were found similar on specimens examined but they are distinct from other species by the shape of the hypostomium and the features of the mandible.

See remarks under *C. varipes* for additional comments.

Distribution. Reported from GEORGIA (Patrick *et al.* 1967), to the NORTH-WEST TERRITORIES (Rosenberg & Wiens 1976).

Material examined. Holotype female, Algonquin, Illinois, 6-4-94-55 (W. A. Nason); in the Illinois Natural History Survey Collection, Urbana. On slide: ONTARIO Elmira, Salem Creek, 14 ♂♂ 19.V.6.VIII.77, 3 ♂♂ 25.V-1.VI.78, 13 ♀♀ 20.V-2.VI.77, 1 intersex 18.V.77. Associated larva-pupa-adult: Conestogo, Conestogo River, 29.V.78 (1 ♂♀, 2 ♀♀), 31.V.78 (1 ♂). In alcohol: Elmira, Salem Creek, 240 ♂♂, 270 ♀♀ from May 1976 to September 1978.

***Cricotopus (Cricotopus) annulator* Goetghebuer**

Cricotopus annulator Goetghebuer, 1927:52 (original description, male).

Cricotopus irwini, Sublette & Sublette, 1971:97 (original description, male), NEW SYNONYM.

Cricotopus (Cricotopus) annulator Goetgh. Hirvenoja, 1973:202 (redescription, keys, adults, pupa, larva).

MALE (Fig. 7)

Length. 2.6 (2.3-3.2) mm; thorax 0.8 (0.7-1.0) mm; abdomen 1.7 (1.6-2.2) mm.

Thorax. Shining. Mesonotal bands not contrasting with the dark brown ground colour.

Wing. Transparent, with a pale brownish tint. Length 1551 (1313-1980) μm , width 491 (404-606) μm . Setae: first axillary sclerite with one seta; remigium 1; squama 6.1 (4-7); vein R 3.7 (3-5) proximal; R_1 0; R_{4+5} 0. Anal lobe obtuse, not produced.

Legs. Fore tibia with white ring, distal dark brown band about 4-5 times larger than basal dark band; longer, more or less distinct, pale brown or yellowish ring on mid and hind tibiae. Fore tarsi brown, mid and hind tarsi paler. Sensilla chaetica 2.1 (0-6), sometimes present on basal 1/5 of mid tarsi 1, always present, 5.6 (5-7), on basal 1/5-1/6 of hind tarsi 1.

Abdomen. Greyish brown in general. Tergites I-II somewhat lighter, sometimes whitish in paler specimens, III with narrow more or less distinct anterior and posterior pale margins, IV-V paler on the first 1/3 and posterior 1/6, VI-VII with paler coloration on posterior 1/5, VIII dark brown. On tergites III-IV median setae in double row at least between posterior muscle marks; lateral setae uniserial with often a beginning of double row; transverse uniserial row of setae present posteriorly. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	3.8 (2-5)	10.3 (6-14)
Tergite IV	4.3 (3-6)	8.8 (7-16)

Hypopygium. White. Gonocoxite length 182 (148-200) μm , gonostylus length 33 (43-70) μm . Anal point absent. Basal lobe biramous, well developed; anterior part round, densely strongly setose, larger than posterior part, directed inwards, posterior part small, narrowly triangular, obliquely directed backwards. Inner edge of gonostylus large, well developed, with a small apical spine.

FEMALE (Fig. 7)

Length. 2.5 (2.0-3.0) mm; thorax 0.8 (0.7-1.0) mm; abdomen 1.6 (1.2-2.1) mm.

Antenna. Preapical seta present 232 (209-278) μm .

Thorax. Shining. Coloration as in the male.

Wing. Transparent, with a pale brownish tint. Length 1776 (1636-2000) μm , width 663 (606-747) μm . Setae: first axillary sclerite with one seta; remigium 1.1 (1-2); squama 7.4 (6-10); vein R 6.7 (4-9); R_1 0; R_{4+5} 3.8 (3-5) distal. Anal lobe obtuse.

Legs. Coloration as in the male. There were 7.8 (5-9) sensilla chaetica on basal 1/4-1/7 of mid tarsi 1, and 8.2 (6-10) on basal 1/5 (1/4-1/6) of hind tarsi 1.

Abdomen. Coloration similar to that of male, greyish brown. Tergites I-II generally paler than others sometime whitish, III-VII with distinct pale band on anterior 1/5 and a more or less distinct pale posterior margin in some specimens, VIII brown. On tergites III-IV median setae in double row at least posteriorly; lateral setae uniserial, more numerous caudad; transverse posterior row of setae present, uniserial. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	2.8 (2-3)	6.8 (5-10)
Tergite IV	2.9 (2-3)	7.5 (5-10)

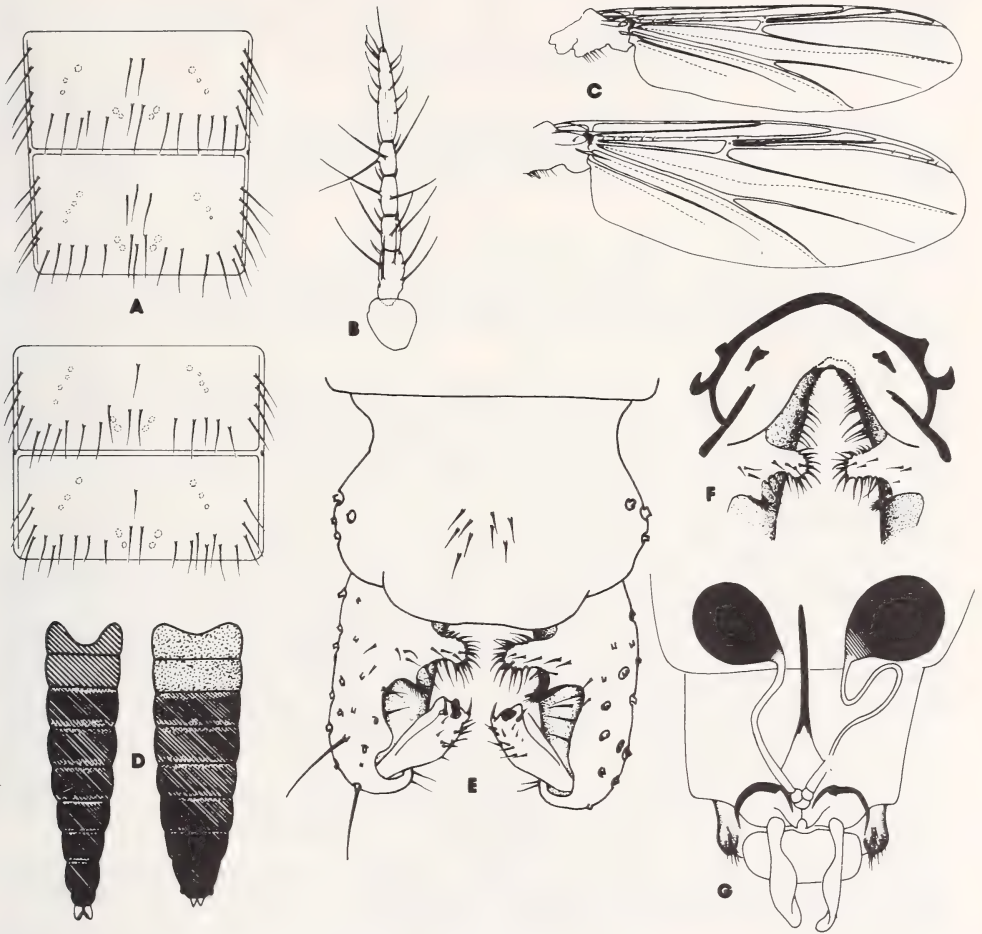


FIG. 7. *Cricotopus annulator* Goetghebuer, imagines. A, chaetotaxy on abdominal tergites III-IV of the male (upper), and the female (lower). B, antenna, female. C, wing, male (upper), female (lower). D, abdominal coloration, male (left), female (right). E, male hypopygium, dorsal view. F, male hypopygium, ventral view. G, female genitalia, ventral view.

Genitalia. Cerci white. Spermathecae brown, roundish or ovoid, 97 (78-122) μm long with a gradually narrowed seminal capsule. Spermathecal ducts strongly S-shaped, sometimes weakly curved (variability probably an artifact due to the process of mounting in Canada balsam). Lateral sternites of abdominal segment IX moderately developed.

PUPA

None found. The following characters described by Hirvenoja (1973) might help in the recognition of the pupa of this species.

Length about 3.5 mm. Prothoracic horn 15 (11-24) μm wide, 140 (113-184) μm long, acuminate and covered by spinules apically. Frontal tubercle and frontal setae absent. Pedes spurii B on segment II moderately developed, absent on segment III.

LARVA

None found. The following distinctive features are taken from Hirvenoja (1973), who bases his description on material of *C. bituberculatus* Goet. which he places in synonymy with *C. annulator*.

Length about 6 mm. Premandibular brush not visible. Antennal ratio 0.65-0.74. Lateral hair tufts (1+) of the abdominal segment I-VI small, at most the length of the segment, with more than 10 setae. Mandible dark, distally wholly black; outer edge almost smooth but with at least a notch. Hypostomium dark with median tooth about 2 times as wide as the first lateral tooth; the second lateral tooth small, the remaining teeth increasing somewhat in size.

Remarks. Small, unicoloured, dark-brown species which shows a distinctive, basal lobe in the male hypopygium, and the female having a few serial, abdominal setae, large spermathecae and curved spermathecal ducts. The types of *C. irwini* Sublette & Sublette and the material from Salem Creek correspond fairly well to the redescription of *C. annulator* by Hirvenoja (1973). Only minor differences from the European species were noted, among others: smaller wing size, slightly lower male antennal ratio and slightly fewer sensillae chaeticae on female legs. Our figures are averages and several specimens fall in the range of variations observed for *C. annulator*. Otherwise, both the type of *C. irwini* and the specimens from Salem Creek key out readily to *C. annulator* and *C. irwini* is considered here to be a synonym. The species is reported for the first time in Ontario.

Distribution. Reported from EUROPE, CANADA, LABRADOR (Hirvenoja 1973); sub *Cricotopus irwini* Sublette & Sublette: CALIFORNIA (Sublette & Sublette 1971).

Material examined. On slide: ONTARIO Elmira, Salem Creek, 4 ♂♂, 1 ♀, 6.V-24.V.1976; 18 ♂♂, 10 ♀♀, 11.V-15.X.1977; 6 ♂♂, 1 ♀, 18.V-1.VI.1978. In alcohol: Elmira, Salem Creek, about 465 ♂♂, 435 ♀♀ from May 1976 to October 1978. Originally described as *Cricotopus irwini* Sublette & Sublette, holotype male, type No. 71262, USNM, (UCR. Ent. Mus. Specimen No. 22067). Deep Canyon, Riverside County, California, 18 May 1964, at light, M. E. Irwin. In the U.S. National Museum Collection, Washington.

Cricotopus (Cricotopus) triannulatus (Macquart)

Chironomus triannulatus Macquart, 1826-202 (original description, adult).

Cricotopus exilis Johannsen, 1905:255 (original description, male, pupa, larva)

NEW SYNONYM

Cricotopus exilis Johannsen, Malloch, 1915:444 (key, larva); Johannsen, 1937: 52 (description, key, pupa, larva); Johannsen in Johannsen & Townes, 1952: 17 (key, adults); Roback, 1957:69 (key, pupa, larva); Sublette, 1967b:517 (redescription, male).

Cricotopus (Cricotopus) triannulatus (Macq.), Hirvenoja, 1973:208 (redescription, key, adults, pupa, larva).

C. (C.) triannulatus (Macq.), Saether, 1977:117 (illustration, female genitalia).

MALE (Fig. 8)

Length. 2.9 (2.4-3.3) mm; thorax 0.9 (0.7-1.0) mm; abdomen 2.2 (1.6-2.3).

Thorax. Shining. Coloration variable with mesonotal bands more or less contrasting with the variable ground colour.

Wings. Transparent. Length 1770 (1454-1879) μm , width 570 (444-667) μm . Setae: first axillary sclerite with 1.4 (1-3) setae; remigium 1.2 (1-2); squama 6.3 (5-8); vein R 5.1 (3-8); R_1 0; R_{4+5} 0; Costa slightly extended beyond R_{4+5} , about $\frac{1}{2}$ length of r-m. Anal lobe variable moderately projected to roundly rectangular or obtuse.

Legs. Fore tibiae with white ring, distal brown band wider; white ring on mid and hind tibiae sometimes more or less obscured. Fore tarsi dark brown; mid and hind tarsi paler, pale brown or yellowish, with tarsi 4 and 5 somewhat darker. Sensilla chaetica, 7.9 (6-12) only on basal $1/4$ - $1/5$ of hind tarsi 1.

Abdomen. Coloration variable. Mature, dark specimens as follows: tergite I pale brown, II brown with narrow, anterior, yellow band, III wholly brown, IV-V brown with anterior $\frac{1}{3}$ - $\frac{2}{3}$ yellow more or less infuscated with brown, VI-VIII dark brown with a pale, narrow band on the posterior $1/5$. In light specimens, tergite I yellow, II and III with a yellow, anterior band and narrow posterior band, IV-V sometimes nearly completely yellow except for a very narrow, brown, posterior band, and VI-VIII also with a narrow, yellowish, anterior band. On tergites III-IV median setae in double row, not numerous; lateral setae uni- to biserial; transverse, uniserial row of setae present posteriorly. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	4 (3-5)	9.7 (8-14)
Tergite IV	4.7 (4-6)	10.7 (8-18)

Hypopygium. White. Gonocoxite length 183 (165-200) μm , gonostylus length 63 (48-70) μm . Anal point absent. Basal lobe biramous; anterior part larger, round with rather strong marginal setae, posterior part triangular, smaller, less setose. Inner edge of gonostylus weakly developed.

FEMALE (Fig. 8)

Length. 2.6 (2.2-2.9) mm; thorax 0.9 (0.8-1.1) mm; abdomen 1.7 (1.4-1.9) mm.

Antenna. Preapical setae present 172 (148-217) μm .

Thorax. Shining. Coloration much lighter than in the male. Mesonotal bands sharply contrasting on yellow ground colour, sometimes infuscated with brown.

Wings. Transparent. Length 1828 (1495-2020) μm , width 683 (606-747) μm . Setae: first axillary sclerite with one seta; remigium 1; squama 7.7 (6-10); vein R 9.1 (8-11); R_1 0.3 (0-1); R_{4+5} . Anal lobe, not produced, obtuse.

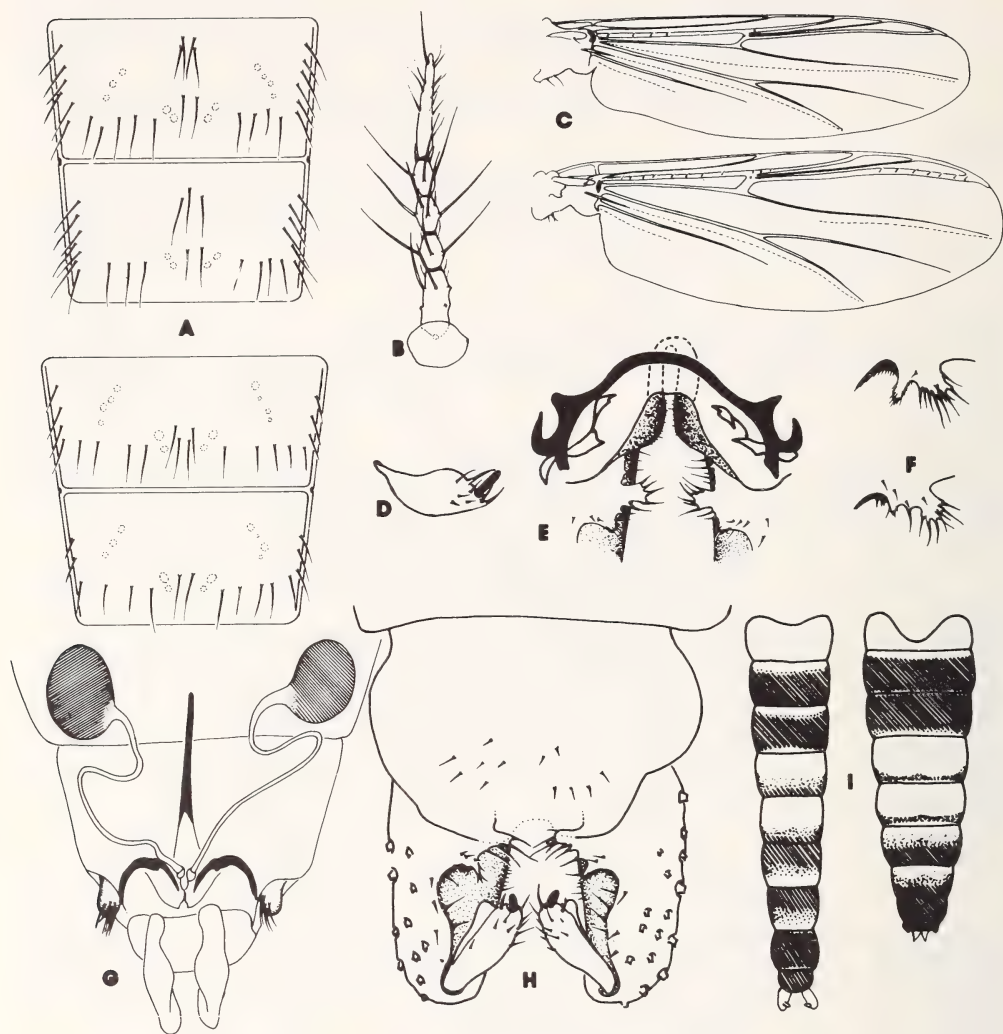


FIG. 8. *Cricotopus triannulatus* (Macquart), imagines. A, chaetotaxy on abdominal tergites III-IV of the male (upper), and the female (lower). B, antenna, female. C, wing, male (upper), female (lower). D, male gonostylus, variation. E, male hypopygium, ventral view. F, basal lobe of gonocoxite, variation. G, female genitalia, ventral view. H, male hypopygium, dorsal view. I, abdominal coloration male (left), female (right).

Legs. Coloration as in the male. There were 10.5 (8-13) sensilla chaetica on basal 1/3 (1/5-5/12) of mid tarsi 1, and 10 (7-13) on basal 1/4 (1/6-1/2) of hind tarsi 1.

Abdomen. General colour pattern more or less as in the male but lighter. Tergite I yellow, II brown with basal 1/5-1/3 yellow, III brown with more or less distinct posterior pale band, IV-V mostly yellow with a narrow, posterior, brown band, VI brown with basal 1/3 yellow, VII brown yellowish or paler on anterior half, VIII brown with a narrow, light, anterior band. On tergites III-IV median setae in double row at least posteriorly, not numerous; lateral setae uniserial; transverse, uniserial row of setae present posteriorly. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	3.7 (3-5)	9.2 (7-13)
Tergite IV	3.3 (2-6)	8.4 (6-11)

Genitalia. Cerci white. Spermathecae dark brown, roundish, oval, or more or less reniform, 101 (87-113) μm long. Spermathecal ducts S-shaped. Lateral sternites of abdominal segment IX well developed.

PUPA (Fig. 9)

Colour: exuvia brownish, paler on abdominal segments I, VII, VIII, darker on cephalothorax.

Length of the exuvia (mm) 3.7 (2.5-4.2); cephalothorax 1.3 (1.2-1.5); abdomen 2.7 (2.2-3.8).

Cephalothorax. Anterior part of notum weakly wrinkled along the eclosion line. Pronotal horn transparent, sharp, covered by spinules on apical 2/3, 122 (93-136) μm long, 24 (19-30) μm wide. Prothoracic horn ratio 5.08 (4.10-6.94). Frontal tubercule absent; frontal setae, 90 (70-113) μm , present on the frontal plate below the middle of the base of the antenna.

Abdomen. Anal lobe length 230 (217-261) μm ; longest anal setae length 146 (139-157) μm . Pedes spurii B present on abdominal segment II weak on III. Setae present on abdominal segments I-VIII:

	I	II	III	IV	V	VI	VII	VIII
dorsals	4	4	4	4-5	4-5	4-5	5	1
laterals	1	2	3	3	3	3	3	5
ventrals	0	3	3	3	3	3	3	0

Tergites: I bare; II with a transverse patch of 93.9 (82-112) recurved hooks, biserial; a very small, spine patch on each side, anterior to the extremity of the hook patch and sometimes another supplementary patch anteriorly, mediad; III-V with three, spine patches: anterior patch reniform, median patch transverse, well separated from anterior patch, but close to posterior transverse patch, VI with a large anterior and a small posterior, spine patch divided in three parts; VII-VIII covered by shagreen patches on the anterior 1/3.

LARVA (Fig. 9)

Fourth-instar larva (exuvia) 3.2-5.2 mm long. Head capsule brownish, darker laterally and posteriorly. Body greenish.

Antenna 70 (61-93) μm long, 0.48 (0.39-0.65) as long as mandible, 5.43 (4.67-6.00) times as long as wide. Lauterborn's organs large, antennal blade

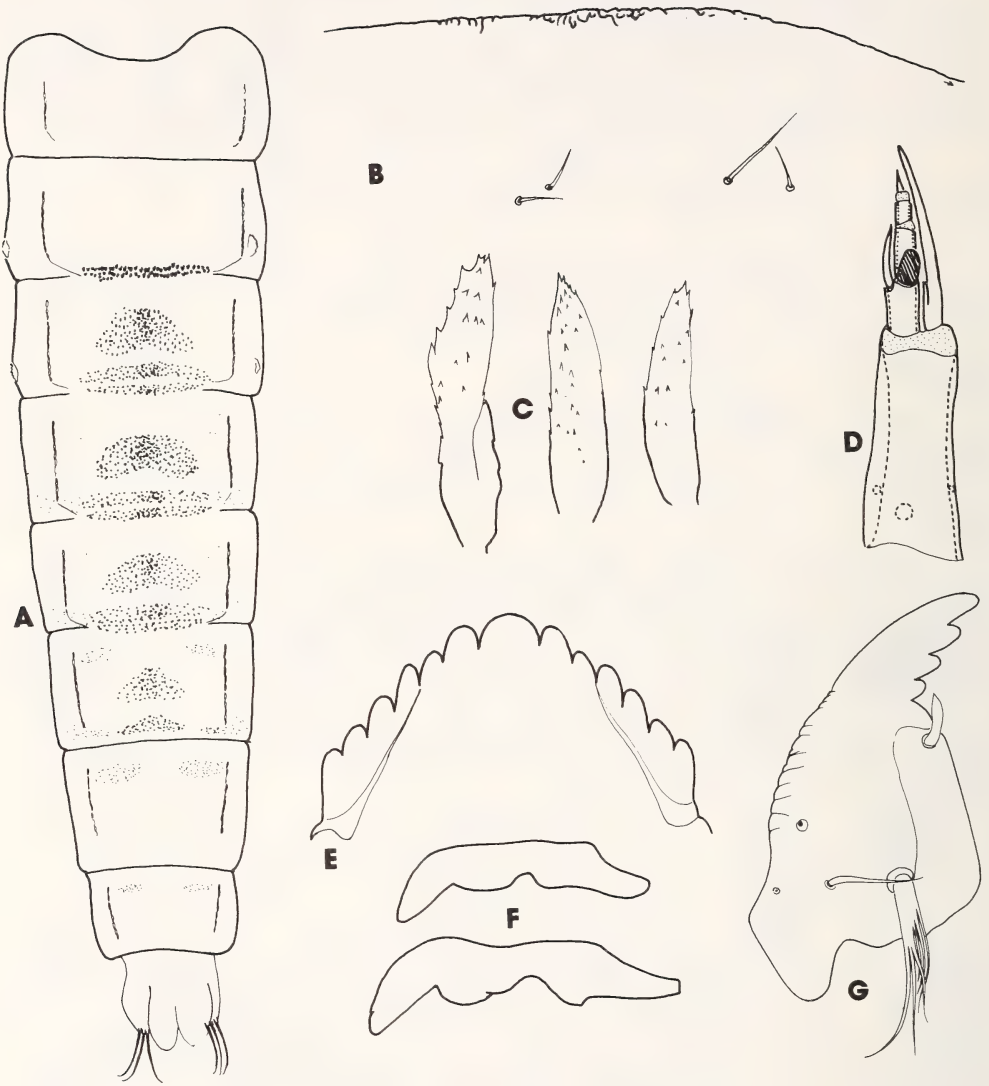


FIG. 9. *Cricotopus triannulatus* (Macquart), pupa A-C, larva D-G. A, ornamentation of pupal exuviae, dorsal view. B, ornamentation along eclosion line and dorsocentral setae. C, prothoracic horn, variation. D, antenna. E, hypostomium, ventral view. F, premandible, variation. G, antenna.

extending to or beyond the apex of antennomere 5, accessory setae to about half of antennomere 3 and sensory seta to the apex of 3. Labral setae SI bifurcated. Epipharynx with four chaetulae laterales and two chaetulae basales; pecten with three small setae.

Premandible simple, brownish, sometimes darker on apical half. Distal part of the mandible dark brown to black, inner margin smooth, outer edge with strong crenulations.

Hypostomium 129 (111-148) μm wide, 77 (70-93) μm long. Hypostomial ratio 0.59 (0.52-0.65). Median tooth and the first two, lateral teeth slightly paler than remaining lateral teeth. Median tooth generally evenly convex 1.84 (1.40-3.00) wider than the first lateral tooth. First lateral tooth rounded, distinctly larger, and separated from the second lateral tooth; lateral teeth 3-6 generally regularly decreasing in size, or about the same size.

Anal gills sausage-shaped. Claws on anterior prolegs and posterior pseudopods about the same brown colour. Lateral hair tuft on abdominal segment I-VI moderately developed 92 (57-114) μm .

Remarks. The colour pattern of the abdomen, with tergites IV-V partly light, separate adults of this species from the others; male and female genitalia are also distinctive. The immatures have the general habitus of those in the *tremulus* group; the presence of frontals, its smaller size and the reniform shape of the anterior, spine patch of tergites II-V, distinguish this species. In the larva, the hypostomium of *C. triannulatus* resembles that of *C. slossonae* but differs from the latter by its larger, second lateral tooth. *C. triannulatus* and *C. infuscatus* are virtually impossible to separate only on the shape of the hypostomium; however the basal portion of the mandible is yellow in this species but distinctly brownish in *C. infuscatus*.

This species is known from North America under the name of *Cricotopus exilis* Johannsen. The type specimen of *C. exilis* as well as the material from Salem Creek correspond to the description of the European species *C. triannulatus* (Macquart) and the name *Cricotopus exilis* Johannsen is placed in synonymy. This species is reported for the first time in Ontario.

Distribution. Reported in North America sub *Cricotopus exilis* Johannsen for EASTERN NORTH AMERICA (Sublette & Sublette 1965, 1971).

Material examined. On slide: ONTARIO, Salem Creek, 7 ♂♂, 13 ♀♀, 20.V-7.X.1976; 15 ♂♂, 19 ♀♀, 5.V-17.X.1967; 2 ♂♂, 5-11.V.1978. Associated larva-pupa-adult: Conestogo, Conestogo River, 19.V.1978 (1 ♂), 19.V.1978 (1 ♂); Elmira, Salem Creek 10.V.1978 (2 ♀♀), 29.V.1978 (1 ♂). Waterloo, Laurel Creek, 6.V.1978 (1 ♂), 8.V.1978 (1 ♂), 11.V.1978 (2 ♂♂), 12.V.1978 (1 ♂). In alcohol, Elmira, Salem Creek, about 1050 ♂♂, 2960 ♀♀ from May 1976 to November 1978. Originally described as *Cricotopus exilis* Johannsen, holotype male, No. 2343, Ithaca, New York, no date. Specimen with a sub-slide of genitalia and antenna desposited in the Cornell University Collection, Ithaca.

***Cricotopus (Cricoptopus) infuscatus* (Malloch)**

Orthocladus (Trichocladus) infuscatus Malloch 1915:517 (original description, male).

Cricotopus infuscatus (Malloch), Johannsen in Johannsen & Townes, 1952:17 (key, adults): Sublette, 1970:62 (redescription, male): Sublette & Sublette, 1971:101 (key, male).

MALE (Fig. 10)

Length 3.1 (2.9-3.6)mm; thorax 1.0 (0.9-1.1) mm; abdomen 2.1 (1.9-2.5) mm.

Thorax. Shining. Mesonotal band sharply contrasting on the yellowish ground colour of thorax, which is infuscated with brown in dark specimens.

Wings. Transparent, with pale brownish tint. Length 1846 (1717-1959) μm , width 568 (505-626) μm . Setae: first axillary sclerite with one seta; squama 10.8 (8-20); vein R 6.1 (4-8); R_1 0; R_{4+5} 0. Anal lobe varying from weakly produced to rectangularly obtuse, generally not produced however.

Legs. No light ring on fore tibiae; dark brown mid and hind tibiae with a more or less distinct pale ring, proximal and apical, dark-brown band about equal in size. All fore tarsi dark brown; mid and hind tarsi brown, paler than on fore legs, however. Sensilla chaetica, 8 (6-9) on basal 1/5 (1/4-1/8) of fore tarsi 1 only.

Abdomen. All tergites brown, II-VI more or less distinctly paler on anterior half, VI-VII generally with a pale band on posterior 1/4. Distribution of abdominal setae extremely variable. On tergites III-IV median setae in two groups, instead of in a double row, with a tendency toward an anterior transverse row; lateral setae more or less distinctly biserial; transverse uniserial to biserial row of setae present posteriorly. In some specimens, quite distinctive, anterior and posterior, transverse rows of setae are present, with lateral setae more or less dispersed, or serial. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	7.6 (2-12)	15.3 (12-20)
Tergite IV	8.9 (4-13)	18.7 (13-26)

Hypopygium. Brown. Gonocoxite length 205 (191-226) μm , gonostylus length 74 (65-87) μm . Anal point absent. Posterior part of basal lobe biramous directed obliquely backwards with several, small, marginal setae, anterior part more or less perpendicularly directed inwards with few, stronger, marginal setae. Inner edge of gonostylus well developed, apically produced in a triangular process. Apical spine strong.

FEMALE (Fig. 10)

Length 3.2 (2.6-3.7) mm; thorax 1.0 (0.9-1.2) mm; abdomen 2.2 (1.7-2.4) mm.

Antenna. Preapical seta present 164 (139-209) μm .

Thorax. Shining. Coloration as in the male, but distinctly lighter: mesonotal bands sharply contrasting on the yellowish, ground colour.

Wings. Transparent, with a pale, brownish tint. Length 1955 (1717-2303) μm , width 709 (646-788) μm . Setae: first axillary sclerite with 1 seta; remigium 1; squama 10.6 (8-13); vein R 9.2 (7-11); R_1 4.7 (3-8); R_{4+5} 5.0 (4-6) distal. Anal lobe rectangularly obtuse.

Legs. Coloration as in the male. There were 11.6 (7-16) sensilla chaetica on basal 1/3 of fore tarsi 1 and 13.3 (11-19) on 1/4-1/5 of hind tarsi 1.

Abdomen. Coloration similar to that of the male, but generally with a pale band on posterior 1/5-1/7 of tergites II-VII. Abdominal coloration in teneral or young adults very pale varying from yellowish or greenish to pale brown or a more

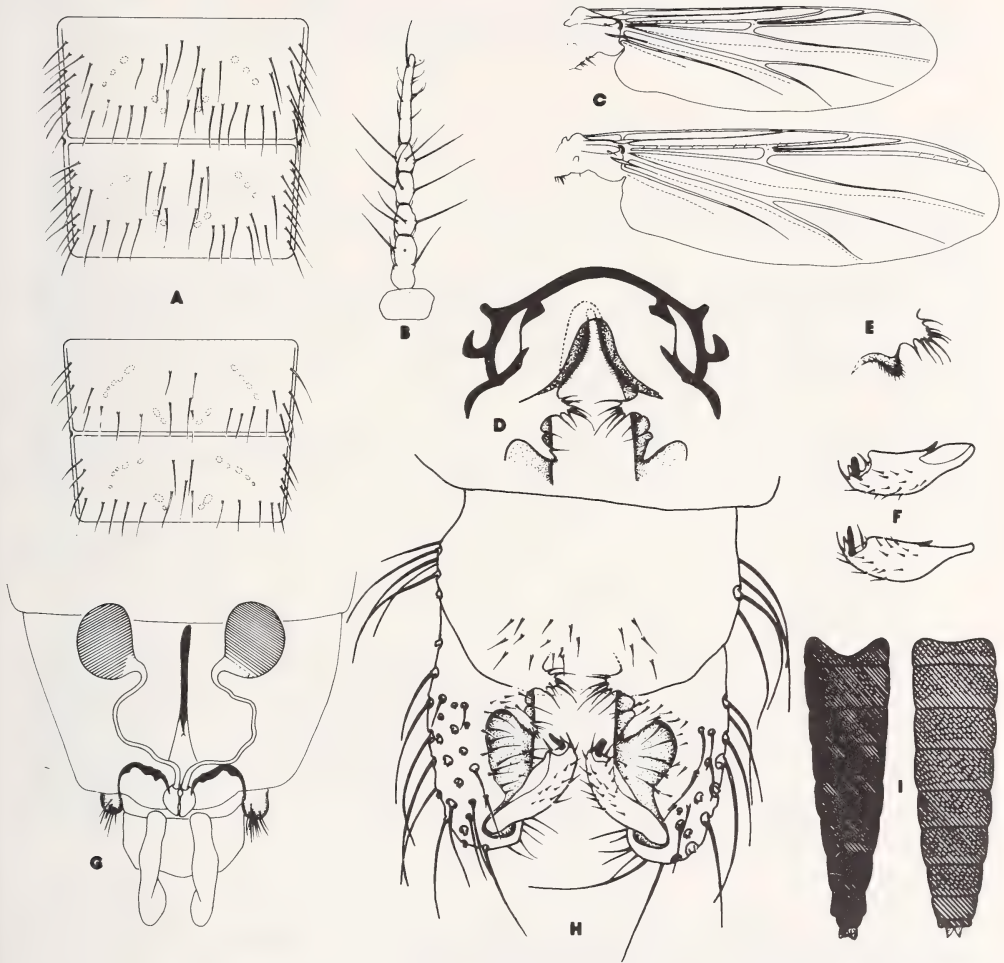


FIG. 10. *Cricotopus infuscatus* (Malloch), imagines. A, chaetotaxy on abdominal tergites III-IV of the male (upper), and the female (lower). B, antenna, female. C, wing, male (upper), female (lower). D, male hypopygium, ventral view. E, male gonostylus, variation. F, basal lobe of gonocoxite, variation. G, female genitalia, ventral view. H, male hypopygium, dorsal view. I, abdominal coloration, male (left), female (right).

or less infuscated pattern. On tergites III-IV median setae biserial; lateral setae uniserial; transverse, uniserial, row of setae present posteriorly. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	5.2 (4-11)	10.4 (7-13)
Tergite IV	5.3 (4-10)	10.3 (7-12)

Genitalia. Cerci whitish with greenish tint plus a more or less distinct brown infuscation. Spermathecae more or less rounded 87 (61-113) μm long, 79 (61-96) μm wide. Spermathecal ducts S-shaped. Lateral sternites of abdominal segment IX moderately developed.

PUPA (Fig. 11)

Colour: brownish.

Length of the exuvia (mm) 4.7 (3.6-4.9), cephalothorax 1.3 (1.1-1.5), abdomen 3.1 (2.5-3.4).

Cephalothorax. Anterior part of notum nearly smooth, weakly wrinkled along the eclosion line. Pronotal horn, transparent, mostly covered by spinules, 125 (91-152) μm long, 27 (16-36) μm wide. Prothoracic horn ratio 4.83 (2.93-7.22). Frontal tubercule absent; frontal setae, 84 (70-130) μm , on the frontal plate, present below the middle of the base of the antenna.

Abdomen. Anal lobe length 289 (243-322) μm , longest anal seta length 148 (122-174) μm . Pedes spurii B present on abdominal segment II and very weak on III. Setae present on abdominal segments I-VIII:

	I	II	III	IV	V	VI	VII	VIII
dorsals	3	4	4	4	4	5	5	1
laterals	1	2	3	3	3	3	3	5
ventrals	1	3	3	3	4	4	4	0

Tergites: I bare; II usually with only a posterior, transverse patch of 99.5 (92-112) recurved spines, biserial but sometimes with an extra small, transverse, spine hatch anteriorly; III-V with three spine patches; anterior patch larger, more or less reniform well-separated from median and posterior, transverse patches, which are close to one another; VI with a large, anterior, reniform spine patch and a posterior, elongated, transverse patch usually divided in three parts; VII-VIII with a patch of shagreen on each side of basal 1/3.

LARVA (Fig. 11)

Fourth-instar larva (exuvia) 3.6-6.6 mm long. Head capsule brownish somewhat darker posteriorly and laterally; body greenish.

Antenna 63 (51-71) μm long, 0.41 (0.35-0.45) as long as mandible, 4.22 (3.75-5.00) times as long as wide. Lauterborn's organs well developed, rather large, antennal blade extending beyond or to the apex of antennomere 5, accessory seta to the basal 1/3 of antennomere 3 and sensory seta to the apex of 3 or base of 4. Antennal ratio 0.55 (0.43-0.66). Labral setae SI bifurcated. Epipharynx with four chaetulae laterales and two chaetulae basales; pecten with three small setae.

Premandible simple, large at base, brown, darker on apical half in some specimens. Distal part of the mandible dark brown to black, basal part brownish, inner margin smooth, outer edge somewhat sinuate, with strong crenulations.

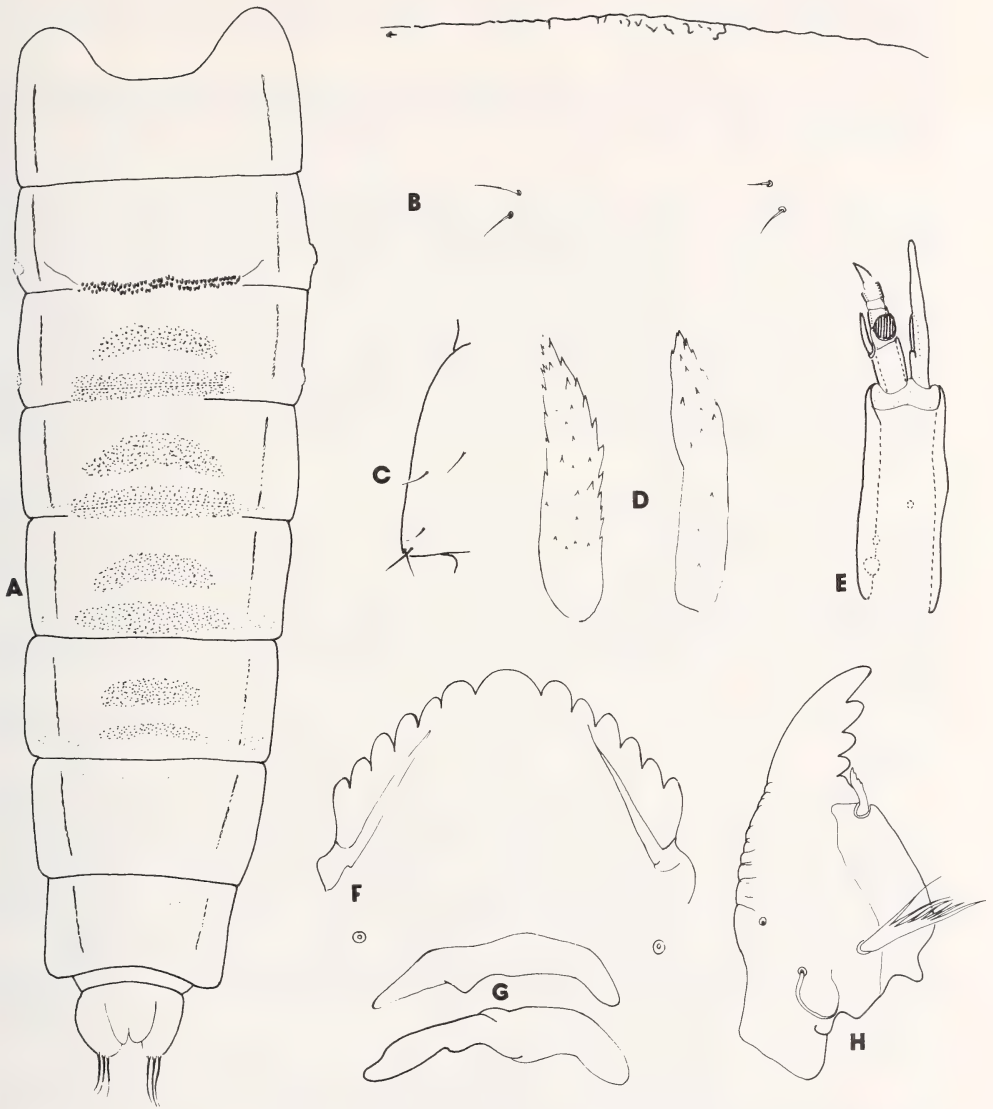


FIG. 11. *Cricotopus infuscatus* (Malloch), pupa A-D, larva E-H. A, ornamentation of pupal exuvia, dorsal view. B, ornamentation along eclosion line and dorsocentral setae. C, lateral setae on abdominal tergite VIII. D, prothoracic horn, variation. E, antenna. F, hypostomium, ventral view. G, premandible, variation. H, mandible.

Hypostomium 142 (130-159) μm wide, 79 (68-84) μm long. Hypostomial ratio 0.56 (0.50-0.61). Median tooth and the first two, lateral teeth indistinctly paler than the remaining teeth. Median tooth convex 1.86 (1.50-2.20) as wide as the first lateral tooth. First, lateral tooth rounded, distinctly separated from the second, lateral tooth, and about twice as large. Lateral teeth 3-6, triangular, and regularly decreasing in size.

Anal gills sausage-shaped. Pseudopodal claws and anterior proleg claws about the same size. Lateral hair-tufts on abdominal segments I-VI well developed 132 (102-159) μm long.

Remarks. *Cricotopus infuscatus* was the only medium to large species with infuscated abdomen and dark brown, mesonotal bands sharply contrasting with the yellowish, ground colour of thorax, and with light ring absent on fore tibiae. Furthermore, males and females have distinctive brownish genitalia. The pupa which has the general habitus of those of the *tremulus*-group is readily separated from other members of the group by the presence of frontals, its larger size and the shape of the anterior, spine patch on tergites III-V which is more elongated than in *C. triannulatus*. The larva of *C. infuscatus* can be separated from that of other species by the stronger, second lateral tooth of the hypostomium and the crenulated outer edge of the mandible which is also distinctly brownish basally, not yellow as in *C. triannulatus*.

This species does not fit exactly into any of the species groups given by Hirvenoja (1973). The female and immatures readily key out to the *tremulus*-group but the male keys to the *fuscus* group on the basis of its multiserial lateral setae on the abdomen, and its numerous median setae irregularly distributed. Nevertheless, the biramous basal lobe of the gonocoxite is well developed as in most members of the *tremulus*-group; *C. infuscatus* probably belongs here while showing some relation to the *fuscus*-group. This species is reported for the first time in Ontario.

Distribution. Reported from: CENTRAL U.S. (Sublette & Sublette 1965, 1971).

Material examined. Holotype male, slide no. 3059, Peoria, Illinois, October 22, 1914, at light (C. A. Hart). In the Illinois Natural History Survey Collection, Urbana. On slide: ONTARIO, Elmira, Salem Creek, 8 ♂♂, 21.V-11.X.1976; 10 ♂♂, 12 ♀♀, 29.V-22.X.1977; 5 ♂♂, 24.V.1978. Associated larva-pupa-adult: Elmira, Canagagigue River Lower East, 4.V.1976, K. Dance (1 ♂); Elmira, Canagagigue River 22.V.1978 (1 ♂, 2 ♀♀); Elmira, Salem Creek 11.V.1978 (1 ♀), 22.V.1978 (1 ♀), 30.V.1978 (1 ♀); Conestogo, Conestogo River 20.V.1978 1 ♂, 2 ♀♀; Waterloo, Laurel Creek 12.V.1978 (1 ♀). In alcohol: Elmira, Salem Creek, about 260 ♂♂, 1020 ♀♀ from May to October 1978.

***Cricotopus (Cricotopus) politus* (Coquillett)**

Orthocladius politus Coquillett, 1902:93 (original description, male).

Orthocladius politus Coquillett, Johannsen, 1905:268 (redescription, male).

Trichocladius politus (Coquillett), Johannsen, 1908:283 (redescription, adults): Malloch 1915:516 (redescription, adults).

Cricotopus politus (Coquillett), Johannsen in Johannsen & Townes, 1952:17 (key, adults).

Orthocladius politus Coquillett [*Cricotopus politus* (Coquillett)], Sublette, 1966b: 593 (redescription, male).

MALE (Fig. 12)

Length. 3.2 (2.7-3.7) mm; thorax 0.9 (0.8-1.1) mm; abdomen 2.3 (1.9-2.6) mm.

Thorax. Shining. Mesonotal bands, sharply contrasting on the yellow ground colour.

Wings. Transparent, brownish. Length 1830 (1616-2020) μm , width 608 (525-768) μm . Setae: first axillary sclerite with one seta; remigium 1; squama 8.7 (8-11); vein R 4.7 (2-6) proximal; R_1 0; R_{4+5} 0. Anal lobe slightly produced or rectangular.

Legs. Femora brown yellow on basal. No light ring on tibiae; fore tibiae brown, mid and hind tibiae brownish; tarsi with similar coloration. Sensilla chaetica not numerous 1.3 (1-3) on the basal 1/25 of mid tarsi 1 and 5.6 (4-8) on basal 1/8-1/5 of fore tarsi 1.

Abdomen. Strongly shining. Tergites brownish yellow becoming darker toward the apex with a distinct greenish tint; somewhat paler on anterior 1/4-1/2 of tergites II-VII. On tergites III and IV median setae more or less distinctly in double row; lateral setae uniserial on each side; also forming a transverse row posteriorly as well as another transverse row near the middle of tergites in line with the anterior median setae. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	6.5 (4-9)	12.1 (10-15)
Tergite IV	6.1 (4-7)	12.8 (8-13)

Hypopygium brownish. Length of gonostylus 70 (61-78) μm , length of gonocoxite 195 (165-235) μm . Anal point absent. Basal lobe well developed curved backwards. Inner, convex edge of gonostylus strongly triangular.

FEMALE (Fig. 12)

Length 2.8 (2.2-4.0) mm; thorax 1.0 (0.8-1.1) mm; abdomen 1.8 (1.5-2.3) mm.

Antenna. Apical seta present 70 (61-80) μm .

Thorax. Coloration as in the male. However, preepisternum II is yellowish ventrally with two, brown, anterior spots and a brown stripe laterally.

Wings. Transparent, brownish. Length 1927 (1717-2060) μm , width 729 (646-788) μm . Setae: first axillary sclerite with one seta; remigium 1; squama 9.3 (8-11); vein R 10 (7-13); R_1 2.8 (1-6); R_{4+5} 4.4 (3-6) distal. Anal lobe not produced, obtuse.

Legs. Coloration as in the male. There were 10.2 (8-13) sensilla chaetica on basal 1/4 of mid tarsi 1 and 6.8 (6-9) on basal 1/5 of hind tarsi 1.

Abdomen. Coloration as in the male but somewhat lighter, sometimes whitish or pale greenish. On tergites III-IV median setae more or less distinctly in double row; lateral setae uniserial on each side, and also forming two transverse rows, one posterior and one near the middle including the anterior, median setae. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	4.8 (4-6)	8.9 (7-15)
Tergite IV	5.1 (4-8)	10.6 (8-16)

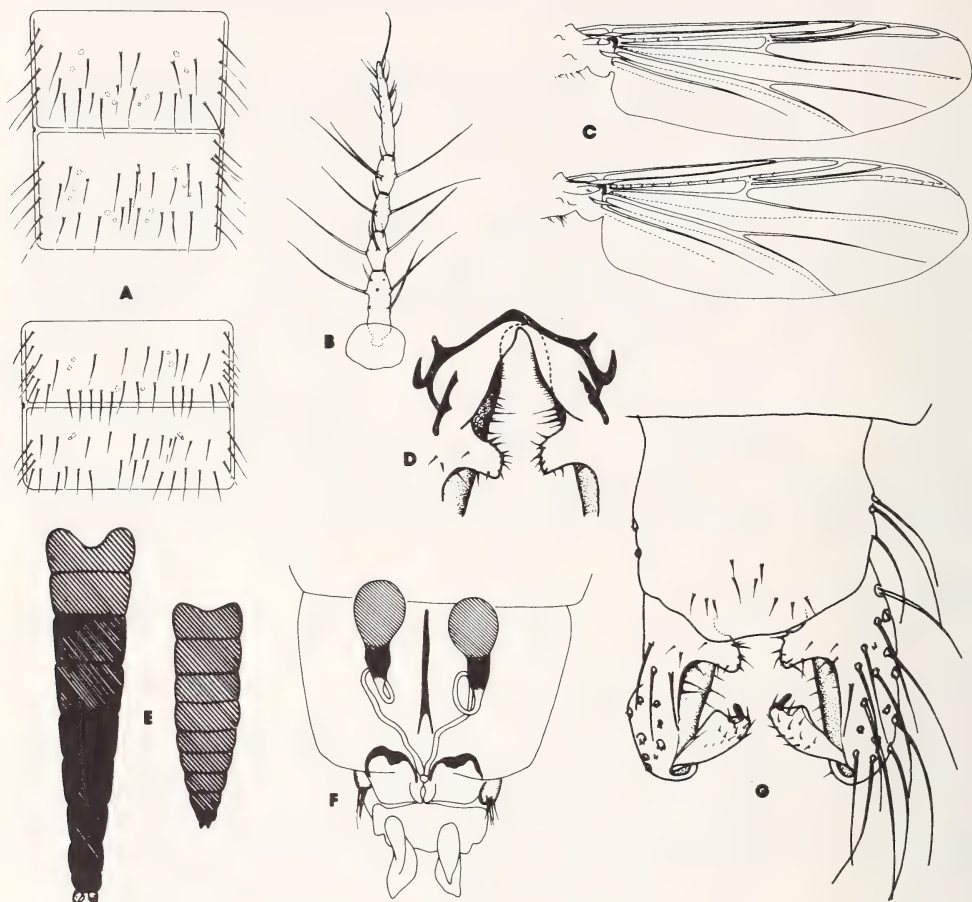


FIG. 12. *Cricotopus politus* (Coquillett), imagines. A, chaetotaxy on abdominal tergites III-IV of the male (upper), and the female (lower). B, antenna, female. C, wing, male (upper), female (lower). D, male hypopygium, ventral view. E, abdominal coloration, male (left), female (right). F, female genitalia, ventral view. G, male hypopygium, dorsal view.

Genitalia. Cerci white or sometimes with a brownish tint. Spermathecae pear-shaped; bulbous part translucent, neck dark brown. Spermathecal duct with a complete loop. Lateral sternites of abdominal segment IX moderately developed.

PUPA (Fig. 13)

(n=3). Colour of the exuvia pale brown gradually becoming paler posteriorly.

Length of the exuvia (mm) 2.1 (1.9-2.2), cephalothorax 0.6 (0.6-0.7), abdomen 1.4 (1.3-1.5).

Cephalothorax. Anterior and median part of notum granular in a narrow band along eclosion line. Pronotal horn transparent with a brownish tint and numerous spinules on apical half 487 (470-513) μm long, 61 (52-70) μm wide. Prothoracic horn ratio 8.1 (7.4-9.2). Frontal tubercule and frontal setae absent. A small patch of granulations on the inner edge of pedicel.

Abdomen. Length of anal lobe 252 (235-287) μm ; length of the longest anal seta 136 (130-139) μm . Pedes spurii B robust, present on segments II and III. Setae present on abdominal segments I-VIII.

	I	II	III	IV	V	VI	VII	VIII
dorsals	3	4	4	5	5	5	5	1
laterals	3	3	3	3	3	3	4	5/(?3)
ventrals	1	2-3	2-3	3-4	3-4	3-4	4	0

Tergites: I bare, II with an anterior small, spine patch, a large, elongated, spine patch and a transverse patch of 56.3 (53-58) recurved spines biserial; III-V with three, well-spaced, spine patches, anterior patch triangular, increasing in size from III to V, median patch elongated covering about 2/3 segment width and well separated from anterior patch, posterior patch transverse, linear and close to median patch and along the segment posterior margin; VI with a large, oval, anterior, spine patch bordered by shagreen patch on each side, and a small, elongated, posterior, spine patch, both well separated; VII-VIII with two, anterior, shagreen patches.

LARVA (Fig. 13)

(n=2). Fourth-instar larva (exuvia) 4.0 5.0 mm long. Head capsule yellowish with a brownish tint.

Antenna 77-82 μm long, 0.53 as long as mandible, 4.86-5.14 times as long as wide. Lauterborn's organs small, antennal blade extending beyond the apex of antennomere 5, accessory seta to the basal 1/3 of antennomere 3, and sensory seta until 2/3 of antennomere 3. Antennal ratio 0.73-0.75.

Labral setae SI bifurcated. Epipharynx with five chaetulae laterales and two chaetulae basales; pecten with three small setae.

Premandible simple. Distal part of the mandible dark brown to black with smooth inner margin and smooth outer edge.

Hypostomium 123-134 μm wide, 64-73 μm long. Hypostomial ratio 0.52-0.54. Median tooth and first two, lateral teeth somewhat paler by transmitted light. Median tooth 2.00-2.33 as wide as the first lateral tooth. Lateral teeth 1-6 more or less regularly decreasing in size; however, the first, lateral tooth is partly fused with median tooth.

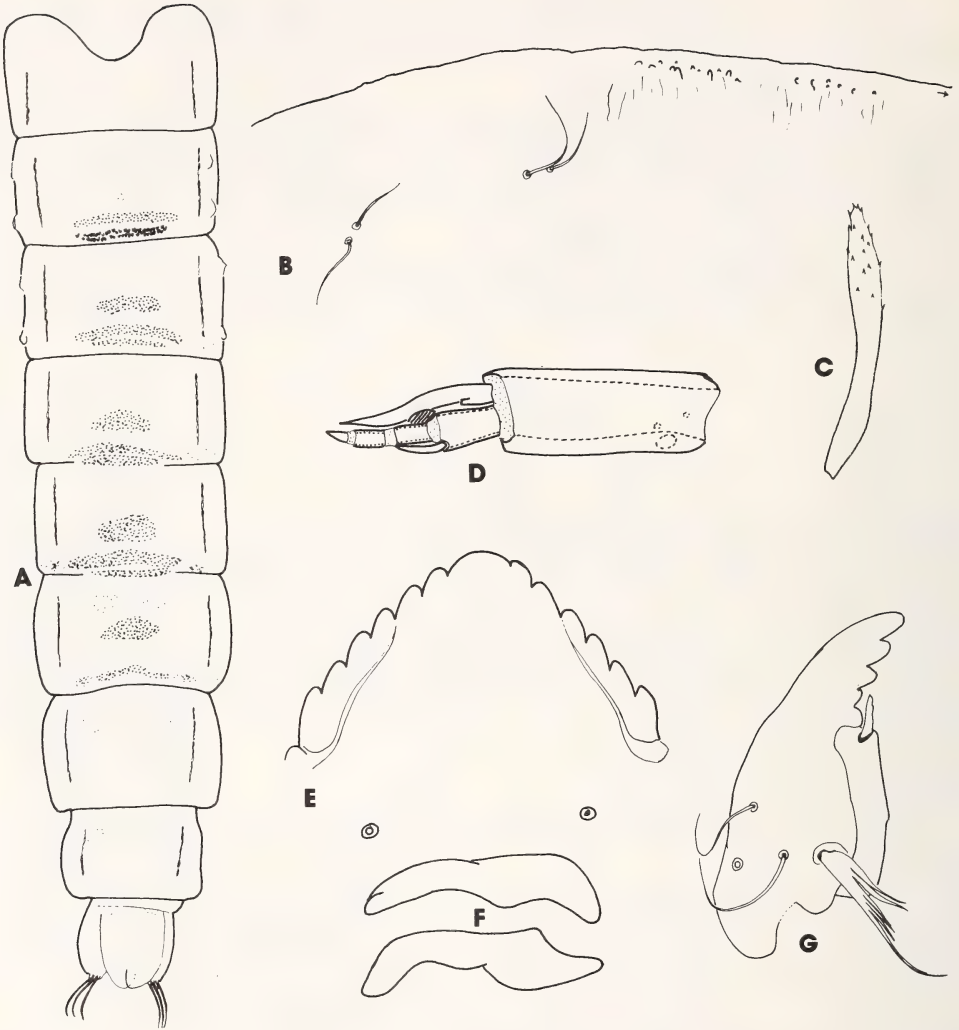


FIG. 13. *Cricotopus politus* (Coquillett), pupa A-C, D-G. A, ornamentation of pupal exuvia, dorsal view. B, ornamentation along eclosion line and dorsocentral setae. C, prothoracic horn. D, antenna. E, hypostomium, ventral view. F, premandible, variation. G, mandible.

Anal gills sausage-shaped. Brown claws on anterior pseudopods. Lateral hair-tufts on abdominal segments I-VI reduced 23-45 μm .

Remarks. The adults of this species have a very distinctive colour pattern and unique male and female genitalia. In the pupa, the presence of a transverse, spine patch in front of the patch of recurved spines on tergite II readily separates this species from others. The hypostomium with lateral teeth about the same size and the smooth, outer edge of the mandible are two characters which distinguish this larva from the others.

The Nearctic *C. politus* is closely related to the European species of the *cylindraceus*- group and to a lesser extent to the *fuscus*- group. In the male, the anterior, transverse row of setae on the tergites is present as in the males of the *cylindraceus*- group but the basal lobe of the gonocoxite is not notched as in typical species. The female (associated with the male by its similar abdominal chaetotaxy and similar emergence) has the pear-shaped spermathecae of the *fuscus*- group. In the pupa, the frontal setae are absent, but present on the prefrons in the *cylindraceus*- group, and the lateral setae (1+) on segment VIII are well developed but weak in the *cylindraceus*- group. The larva has a hypostomium with a broad, median tooth and subequal, lateral teeth, but in *C. politus* the antennal ratio is distinctly greater, 0.73-0.75, than in the *cylindraceus*- group, $P < 0.5$. For these reasons, it would be reasonable to place *C. politus* in a group of its own, somewhat linked to the European *cylindraceus* and *fuscus*- groups. The species is reported for the first time in Ontario.

Distribution. Reported from COLORADO and FLORIDA to NEW YORK (Sublette & Sublette 1965, Sublette 1967b).

Material examined. Holotype male, number 6174, Washington, D.C. 6.6, H. S. Barber. In the U.S. National Museum Collection, Washington. On slide: ONTARIO: Elmira, Salem Creek, 3 δ δ , 8-22.VIII.1976; 9 δ δ , 10 φ φ 22.V-5.IX.1977; 3 δ δ , 25.V-1.VI.1978. 1 pupa (exuvia) 3.VI.1978. Associated larva-pupa-adult Elmira, Salem Creek, 31.V.1978 (2 δ δ). In alcohol: Elmira, Salem Creek, about 35 δ δ , 30 φ φ from May 1976 to September 1978.

***Cricotopus (Cricotopus) luciae* n.sp.**

MALE (Fig. 14)

Length. 3.5 (3.3-3.9) mm; thorax 1.2 (1.1-1.3) mm; abdomen 2.3 (2.2-2.5) mm.

Thorax. Shining. All thoracic sclerites and ground colour strongly dark brown; antepronotum, postpronotum, space in front and ventral to lateral mesonotal bands and dorsal half of preepisternum II somewhat paler in some specimens.

Wings. Transparent, with a pale brownish tint. Length 2325 (2182-2464) μm , width 701 (646-768) μm . Setae: first axillary sclerite with one seta; remigium one; squama 19.1 (15-24), vein R 9 (7-11), R_1 0, R_{4+5} 0. Costa moderately produced beyond R_{4+5} . Anal lobe moderately produced.

Legs. Fore leg more or less distinctly darker than mid and hind legs. No light ring on tibiae except an indistinct, paler fascia in the middle. Tarsi dark brown, darkest on fore legs. Sensilla chaetica, 7.4 (4-13) on basal 1/6-1/4 of hind tarsus I.

Abdomen. Tergites dark brown throughout; VI-VII with posterior 1/5-1/7 paler, similar pale band sometimes visible in III-VII, with posterior 2/3 on VII

paler in some specimens. On tergites III-IV median setae generally arranged in a short, transverse row anteriorly; lateral setae more or less biserial; transverse row, uni- to biserial, present posteriorly. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	9.8 (6-13)	23 (12-29)
Tergite IV	11 (6-14)	21.9 (10-26)

Hypopygium. Brown. Length of gonocoxite 249 (226-261) μm , length of gonostylus 98 (87-104) μm . True anal point absent but posterior margin of tergite IX medially acuminate. Basal lobe finger-shaped, bare. Inner lobe of gonostylus strongly developed. Apical spine robust and short.

FEMALE (Fig. 14)

Length. 3.4 (2.9-3.9) mm; thorax 1.2 (1.1-2.3) mm; abdomen 2.2 (1.7-2.7) mm.

Antenna. Preapical seta present, 55 (52-57) μm long, fragile, missing on eight specimens.

Thorax. Shining. Coloration as in the male but distinctly lighter; the ground colour which is pale brown to brown not dark brown as in the male. Space in front and ventral to lateral mesonotal bands, antepronotum, postpronotum brownish.

Wings. Transparent, with a weak brownish tint, finely punctate. Length 2285 (2060-2525) μm , width 875 (747-990) μm . First axillary sclerite with one seta; remigium one; squama 16 (13-20); vein R 14 (12-18); R_1 6.7 (4-10); R_{4+5} 6.7 (5-8) distal. Costa moderately projected beyond R_{4+5} . Anal lobe moderately produced.

Legs. Coloration as in the male. There are 5.8 (4-7) sensilla chaetica on basal 1/5 of mid tarsi 1 and 16.9 (14-20) on basal 1/3 of hind tarsi 1.

Abdomen. Coloration as in the male, becoming somewhat darker toward apex. Pale bands, when present, very narrow. On tergites III-IV median setae not numerous, present only on posterior half; lateral setae grouped posteriorly, more or less uniserial; transverse row, uni- to biserial, present posteriorly. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	6.5 (5-10)	14.1 (10-20)
Tergite IV	8.1 (6-12)	14 (8-19)

Genitalia. Cerci brownish. Spermathecae dark brown, roundish 71 (61-78) μm long. Spermathecal ducts strongly curved. Lateral sternites of abdominal segment IX weakly to moderately developed.

IMMATURE STAGES: unknown.

Remarks. This large, brown species lacks white rings on the fore legs. The male hypopygium is very distinctive with finger-shaped, basal lobe, and females have a posterior, transverse row of setae on abdominal tergites, small, round spermathecae and S-curved spermathecal ducts.

This species does not fit in any species-group defined by Hirvenoja (1973) and the male and female genitalia are unique among known *Cricotopus* species. Without the immature stages it is difficult to place *C. luciae* within the genus. The



FIG. 14. *Cricotopus luciae* n.sp., imagines. A, chaetotaxy on abdominal tergites III-IV of the male (upper), and the female (lower). B, antenna, female. C, wing, male (upper), female (lower). D, male hypopygium, dorsal view, holotype. E, male gonostylus, variation. F, basal lobe of gonocoxite, variation. G, female genitalia, ventral view, allotype. H, abdominal coloration, male (left), female (right). I, male hypopygium, dorsal view, holotype.

chaetotaxy of the abdomen—incomplete, anterior, transverse row of setae in the male, and lateral setae located far from the lateral and posterior margins—indicates that this species is relatively close to *C. politus* (Coquillett) and to the *cylindraceus*-group. The creation of a new species-group to include this species seems appropriate but it can only be placed definitively within the genus with the discovery of the immatures.

Distribution. At present known only from southern Ontario but is probably more widely distributed.

Type material. Holotype male, ONTARIO: Elmira, Salem Creek, in emergence trap T 11, between 25.V-1.VI.1978, L. LeSage. Allotype female same data. Paratypes, same locality 7 ♂♂, 3 ♀♀, 18.V-9.X.1976; 15 ♂♂, 10 ♀♀, 3.V-11.V.1977; 4 ♂♂, 2 ♀♀, 18.V-1.VI.1978. In alcohol: 6 ♂♂, 18 ♀♀, 20.V-13.X.1977; 6 ♂♂, 5 ♀♀, 6.V-13.IX.1977; 13 ♂♂, 8 ♀♀, 18.V-18.X.1978. Conestogo, Conestogo River. Swarm E 295, 2 ♂♂. Holotype and allotype in the Canadian National Collection (CNC). Paratypes in the CNC, in the Collection entomologique de l'Université de Montréal, and in the first author's collection.

***Cricotopus (Cricotopus) festivellus* (Kieffer)**

Chironomus festivellus Kieffer, 1906:18 (original description, male).

Cricotopus (Cricotopus) festivellus (Kieffer), Hirvenoja, 1973:225 (description, key, adults, pupa, larva).

MALE (Fig. 15)

Length. 2.9 (2.7-3.3) mm; thorax 0.9 (0.8-1.0) mm; abdomen 2.0 (1.8-2.4) mm.

Thorax. Shining. Mesonotal bands not contrasting with the brown ground colour of the space between them.

Wings. Transparent, with pale brownish tint. Length 1711 (1596-1858) μm , width 545 (505-606) μm . Setae: first axillary sclerite with one seta; remigium one; squama 6.7 (4-9); vein R 2.6 (2-4) proximal; R_1 0, R_{4+5} 0. Anal lobe not produced, obtuse.

Legs. Pure white ring on fore tibia, apical dark brown band about twice as large as the basal dark band; pale brown ring more or less distinct present on mid and hind tibiae. All tarsi brown, but darker on fore legs. There are 3.4 (3-5) sensilla chaetica on basal 1/7 (1/5-1/8) of mid tarsi 1 and 5.7 (5-7) on basal 1/6-1/12 of hind tarsi 1.

Abdomen. Tergites I yellow, II-III almost dark brown or with anterior 1/4-1/8 yellow, and posterior narrow yellow band, IV dark brown on anterior 1/3 and yellow on posterior 2/3, V brown with more or less distinct pale 1/4 anterior band, VI-VII dark brown with more or less distinct pale, narrow, anterior and posterior bands, VIII wholly dark brown. Chaetotaxy:

	median setae	lateral setae
Tergite III	2.2 (2-3)	5.3 (4-7)
Tergite IV	2.3 (2-4)	5.7 (5-7)

Hypopygium. White. Length of gonocoxite 180 (165-191) μm , length of gonostylus 64 (52-70) μm . Anal point absent. Basal lobe large, bent backwards, covered by long setae. Inner edge of gonostylus well developed.

FEMALE (Fig. 15)

Length. 2.9 (2.6-3.2) mm; thorax 0.9 (0.8-1.0) mm. abdomen 1.9 (1.8-2.2) mm.

Antenna. Preapical seta present 246 (217-278) μm .

Thorax. Shining. Coloration as in the male.

Wings. Transparent, with a pale brownish tint. Length 1757 (1535-1919) μm , width 667 (566-727) μm . Setae: first axillary sclerite with one seta; remigium 1.4 (1-2); squama 6.8 (6-8); vein R 6.4 (5-7); R_1 0.1 (0-1); R_{4+5} 3.3 (2-7). Anal lobe obtuse, not produced.

Legs. Coloration as in the male. There are 9.8 (8-12) sensilla chaetica on basal 1/4-1/3 of mid and 10.4 (8-11) on basal 1/4-1/3 of hind tarsi 1.

Abdomen. Colour pattern different from that of the male. Tergite I yellow, II dark brown with a narrow yellow anterior band, III-IV almost all dark brown but sometimes with very narrow, posterior, yellow band, VII-VIII dark brown generally with anterior, yellowish band on 1/4-1/6. On tergites III-IV median setae not numerous, in double row, generally present only posteriorly; lateral setae not numerous, present on posterior half, uniserial; transverse, incomplete, uniserial row of setae present posteriorly, but not distinctive. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	1 (1-1)	4.6 (3-6)
Tergite IV	1-4 (1-2)	3.9 (3-4)

Genitalia. Cerci white. Spermathecae dark brown, oval, 111 (96-130) μm long, 64 (52-96) μm wide. Spermathecal ducts strongly S-curved. Lateral sternites of abdominal segment IX well developed.

PUPA

Colour: exuvia brownish, somewhat paler on tergite I. Length of the exuvium about 3 mm, cephalothorax 1 mm abdomen 2 mm.

Cephalothorax. Anterior part of notum very weakly granular along the eclosion line. Pronotal horn pointed, translucent, almost covered by spinules, 184 μm long, 16 μm wide. Prothoracic horn ratio 11.5. Frontal tubercule absent; frontal setae about 40 μm located on prefrons.

Abdomen. Length of anal lobe 360 μm , length of longest anal setae, 288 μm . Pedes spurii B large on abdominal segment II, weakly indicated on segment III. Setae present on abdominal segments I-VII and muscle marks not clearly visible because the specimen is not properly mounted:

	I	II	III	IV	V	VI	VII	VIII
dorsals	3?	?	?	?	5	5	?	?
laterals	1	3	3	3	3	3	3	4
ventrals	?	4?	4?	4?	4	4	?	0

Tergites: I bare; II with few scattered spinules in front of the transverse patch of 36 recurved spines, biserial; III-V with their spine patches fused together laterally and with a median bare area; VII-VIII with a small, shagreen patch anteriorly on each side.

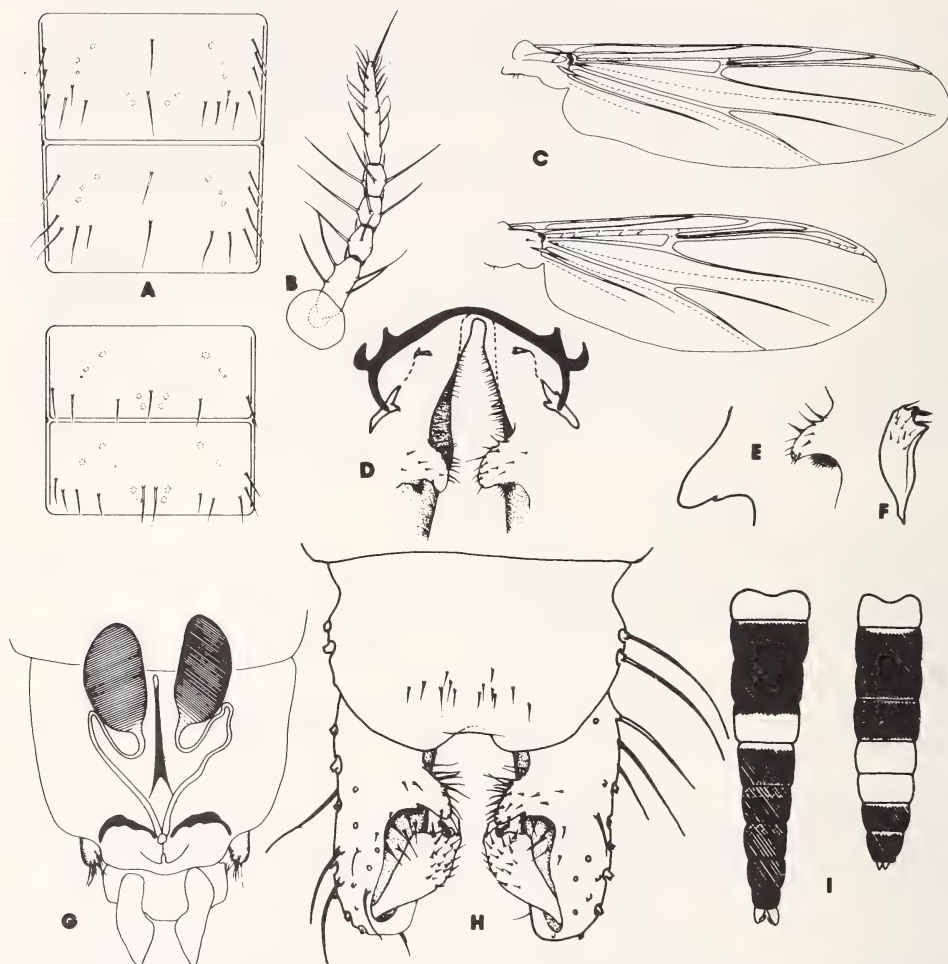


FIG. 15. *Cricotopus festivellus* (Kieffer), imagines. A, chaetotaxy of abdominal tergites III-IV of the male (upper) and the female (lower). B, antenna, female. C, wing, male (upper), female (lower). D, male hypopygium, ventral view. E, basal lobe of gonocoxite, variation. F, gonostylus, variation. G, female genitalia, ventral view (ventral lobe of gonopophysis IX not shown). H, male hypopygium, dorsal view. I, abdominal coloration, male (left), female (right).

LARVA. Unknown.

Remarks. The males of this small, striped, species are very distinctive with abdominal tergites I and posterior 2/3 of IV yellow, and their white hypopygium with large, inner lobe curved backwards. The colour pattern of females is unique among species studied with tergites V-VI yellow. The pupa is distinguished from all others by its large pedes spurii B on abdominal segment II and its spine patches fused together.

Our specimens from Salem Creek are similar to the European species *C. festivellus* (Kieffer) redescribed by Hirvenoja (1973). However, they differ from the latter in several small respects. The colour pattern of the adults is slightly different. In the male, the mean of the antennal ratio is lower than in the European form but ranges overlap, the abdominal chaetotaxy is more reduced. The number of sensilla chaetica on the legs of females is about half the number found in the European specimens and the abdominal chaetotaxy is more reduced in Canadian material. In the pupa examined the prothoracic horn was longer; consequently with a higher ratio than in the European form. All these small differences can be interpreted as normal intraspecific variations in a widely distributed species. However, this opinion could be revised with the discovery of the larvae in North America, and after this species has been studied throughout this continent. This species is reported in Ontario for the first time.

Distribution. Reported from: EUROPE and CANADA, Northwest Territories (Hirvenoja 1973).

Material examined. On slide: ONTARIO, Conestogo, Conestogo River, sweeping along the banks, 6 ♂♂, 24-25.V.1978, Elmira, Salem Creek 3 ♂♂, 2 ♀♀, 18.V-7.IX.1976; 15 ♂♂, 10 ♀♀, 15.V-21.IX.1977; 6 ♂♂, 2 ♀♀, 25.V-1.VI.1978. Waterloo, Laurel Creek, 2 ♂♂, 22.V-27.V.1978. Associated pupa and adult: Green Creek, ONTARIO, 19-22.VI.1967, R.D.M., L.H.-S in the CNC Collection. In alcohol: Elmira, Salem Creek, about 325 ♂♂ and 350 ♀♀ from May 1976 to October 1978.

***Cricotopus (Cricotopus) bicinctus* (Meigen)**

Chironomus bicinctus Meigen, 1818:41 (original description, female).

Cricotopus bicinctus (Meigen), Johannsen, 1905:256 (redescription, male, female); Malloch, 1915:505 (redescription, male, female); Johannsen & Townes, 1952:17 (key, male, female); Roback, 1957a:71 (redescription larva); Darby, 1962:62 (description pupa, larva); Oliver, 1977:98 (comparison with *C. mackenziensis* n. sp.).

Cricotopus (Cricotopus) bicinctus (Meigen), Hirvenoja, 1973:235 (redescription, key, male, female, pupa, larva); Saether, 1977:116 (illustration, female genitalia).

Cricotopus sp. Mason, 1968:83, 1973:83 (illustration, hypostomium, mandible).

MALE (Fig. 16)

Length. 3.4 (3.3-3.7) mm; thorax 1.0 (1.0-1.1) mm; abdomen 2.3 (2.2-2.7) mm.

Thorax. Mesonotal bands, not contrasting on the dark brown ground colour.

Wings. Transparent. Length 1862 (1757-1980) μ m, width 614 (566-646) μ m.

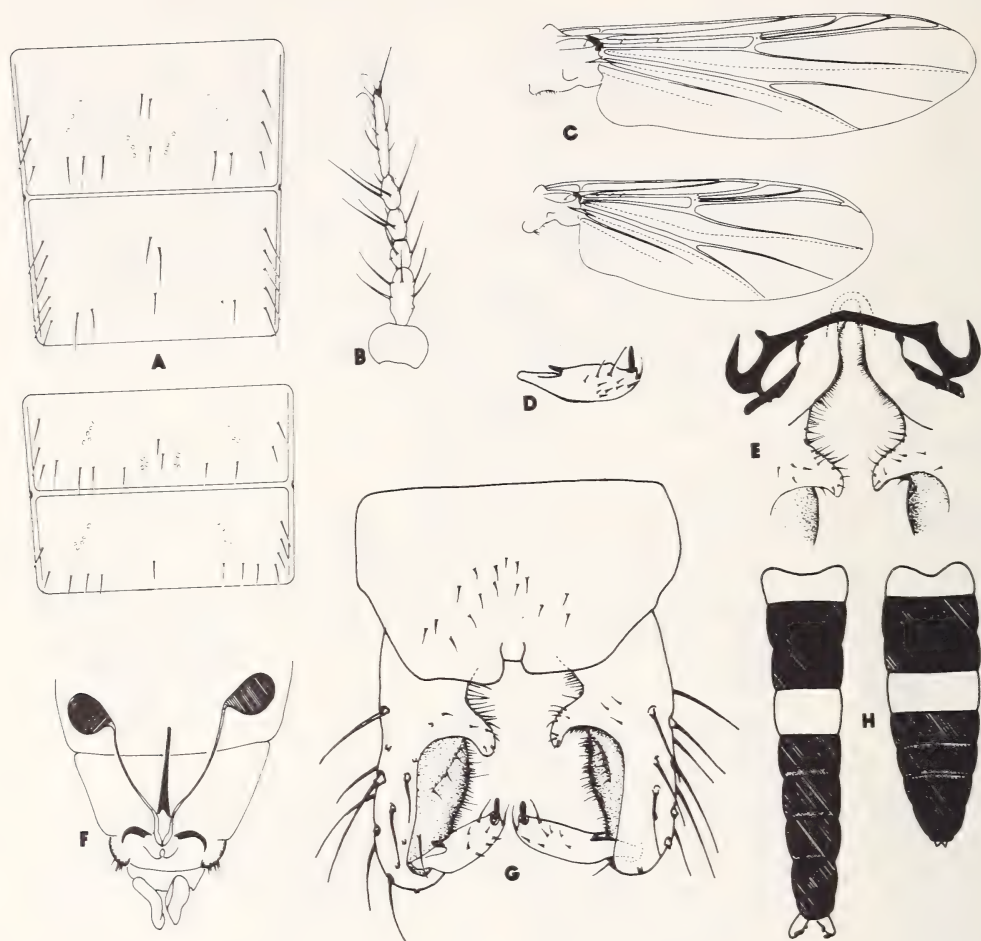


FIG. 16. *Cricotopus bicinctus* (Meigen), imagines. A, chaetotaxy on abdominal tergites III-IV of the male (upper), and the female (lower). B, antenna, female. C, wing, male (upper), female (lower). D, male gonostylus, variation. E, male hypopygium, ventral view. F, female genitalia, ventral view. G, male hypopygium, dorsal view. H, abdominal coloration, male (left), female (right).

Setae: first axillary sclerite with one seta; remigium one, squama 9.6 (8-11); vein R 1.5 (0-4) proximal; R_1 0; R_{4+5} 0. Anal lobe moderately roundly produced.

Legs. White ring present on fore tibiae, apical, brown band about three times longer than basal, brown band; yellowish or pale brown ring on mid and hind tibiae. Fore tarsi dark brown; mid and hind tarsi yellowish to pale brown. Sensilla chaetica 9.4 (7-17) only on basal 1/4-2/5 of the hind tarsi 1.

Abdomen. Tergites I and IV white or yellow. Other tergites dark brown, VI-VIII with narrow, more or less distinct, paler posterior band. II with sometimes an anterior yellow narrow band. On tergites III-IV median setae not numerous, uniserial to biserial; lateral setae uniserial; transverse, incomplete, uniserial row of setae present posteriorly. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	2.7 (2-4)	7.1 (5-13)
Tergite IV	3.4 (2-6)	7.4 (4-12)

Hypopygium. White. Length of gonocoxite 246 (217-278) μm ; length of gonostylus 93 (87-104) μm . Anal point absent. Basal lobe well developed, bent backwards. Inner edge of gonostylus not developed.

FEMALE (Fig. 16)

Length. 2.5 (1.9-2.9) mm; thorax 0.8 (0.6-0.9) mm; abdomen 1.6 (1.3-2.0) mm.

Antenna. Preapical seta present, 59 (55-66) μm .

Thorax. Coloration as in the male but generally paler on the sides and ventrally.

Wings. Transparent. Length 1469 (1293-1616) μm , width 566 (505-626) μm . Setae: first axillary sclerite with one seta; remigium one; squama 7.11 (6-9); vein R 2.6 (1-5) proximal; R_1 0; R_{4+5} 2.0 (1-3) distal. Anal lobe obtuse to rectangularly obtuse.

Legs. Coloration as in the male. There are 12.8 (8-24) sensilla chaetica on basal 1/3-2/5 of mid tarsi 1 and 14 (10-24) on basal 1/3 of hind tarsi 1.

Abdomen. Color of tergites as in the male with tergites I and IV white and others brown. On tergites III-IV, median setae not numerous, uniserial, sometimes biserial; lateral setae uniserial; transverse, incomplete, uniserial row of setae present posteriorly. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	1.2 (1-2)	2.9 (2-4)
Tergite IV	1.1 (1-2)	2.8 (2-5)

Genitalia. Cerci white. Spermathecae brown, ovoid 73 (61-87) μm long. Spermathecal ducts more or less straight. Lateral sternites of abdominal segment IX, shorter than broad, weakly developed.

PUPA (Fig. 17)

Colour. Exuvia brownish, abdominal segments I, VII-VIII paler; thoracic area darker.

Length. Exuvia 3.7 (3.7-4.1) mm, cephalothorax 2.6 (1.9-2.9) mm, abdomen 1.2 (0.8-1.4) mm.

Cephalothorax. Anterior part of notum coarsely granular along eclosion line. Pronotal horn transparent or pale brown with spinules on the apical half, 165 (148-191) μm long, 34 (26-39) μm wide. Prothoracic horn ratio 5.06 (3.40-7.33). Frontal tubercle absent; frontal setae 143 (102-216) μm , located on the frontal plate above the middle of the base of the antenna.

Abdomen. Anal lobe length 275 (243-313) μm . Length of longest anal seta, 137(113-157) μm . Pedes spurii B large, present on segments II and III. Setae present on abdominal segments I-VIII:

	I	II	III	IV	V	VI	VII	VIII
dorsals	4-5	4-5	4-5	5	5	5	5	1
laterals	1	2-3	3	3	3	3	3	4-5
ventrals	0	3	3	3	4	4	4	0

Tergites: I bare, II with a transverse patch of 69.6 (57-81) recurved, biserial spines and a small, lateral patch of shagreen on each side; III-V with three, spine patches more or less separated or sometimes partly fused in the middle; anterior patch triangular, median and posterior patches transverse, more or less fused on V, a small, shagreen patch present laterally on III-IV; VI with two, spine patches; VII-VIII bare.

LARVA (Fig. 17)

Fourth-instar larva (exuvia) 3.8-6.1 mm long. Head capsule brownish, darker laterally and posteriorly; body greenish, whitish in specimens preserved in alcohol. Anterior eye-spot about 1/3 the size of posterior eye-spot.

Antenna 90 (64-105) mm long, 0.60 (0.50-0.71) as long as mandible, 5.90 (5.13-6.43) times as long as wide. Lauterborn's organs small, antennal blade extending until antennomere 4, accessory seta to antennomere 3 and sensory seta to the end of antennomere 3. Antennal ratio 0.54 (0.43-0.66). Labral setae SI bifurcated. Epipharynx with five chaetulae laterales, and two chaetulae basales; pecten with three setae partly fused at the base.

Premandible simple. Premandibular brush absent. Distal part of the mandible dark brown, inner margin distinctly serrate; dorsal edge smooth or weakly wrinkled.

Hypostomium 131 (109-148) μm wide, 69 (61-80) μm long. Hypostomial ratio 0.52 (0.34-0.61). Median tooth and the first two, lateral teeth paler than the remaining lateral teeth. Median tooth convex, 2.87 (2.25-3.71) as wide as the first, lateral tooth. Second, lateral tooth, reduced, about the size of the first, lateral tooth; lateral teeth 3-6 regularly decreasing in size.

Anal gills sausage-shaped slightly pointed at the end, distinctly rounded. The upper, longer pair, scarcely longer than the pseudopods. Claws on pseudopods dark brown, darker than the brownish claws on anterior prolegs. Lateral hair-tufts on abdominal segments I-VI very small 17 (14-23) μm .

Remarks. *C. bicinctus* is probably the commonest species of this genus and is broadly distributed throughout North America. The colour pattern of the body and the male or female genitalia distinguish adults from other species. In the pupa, the following combination of characters is unique among species studied: pedes spurii B well developed, present on abdominal segment II and III, small, shagreen patch on each side on II, spine patches fused together on V and rough granulation along the eclosion line. The larva is readily separated by the serrate, inner margin

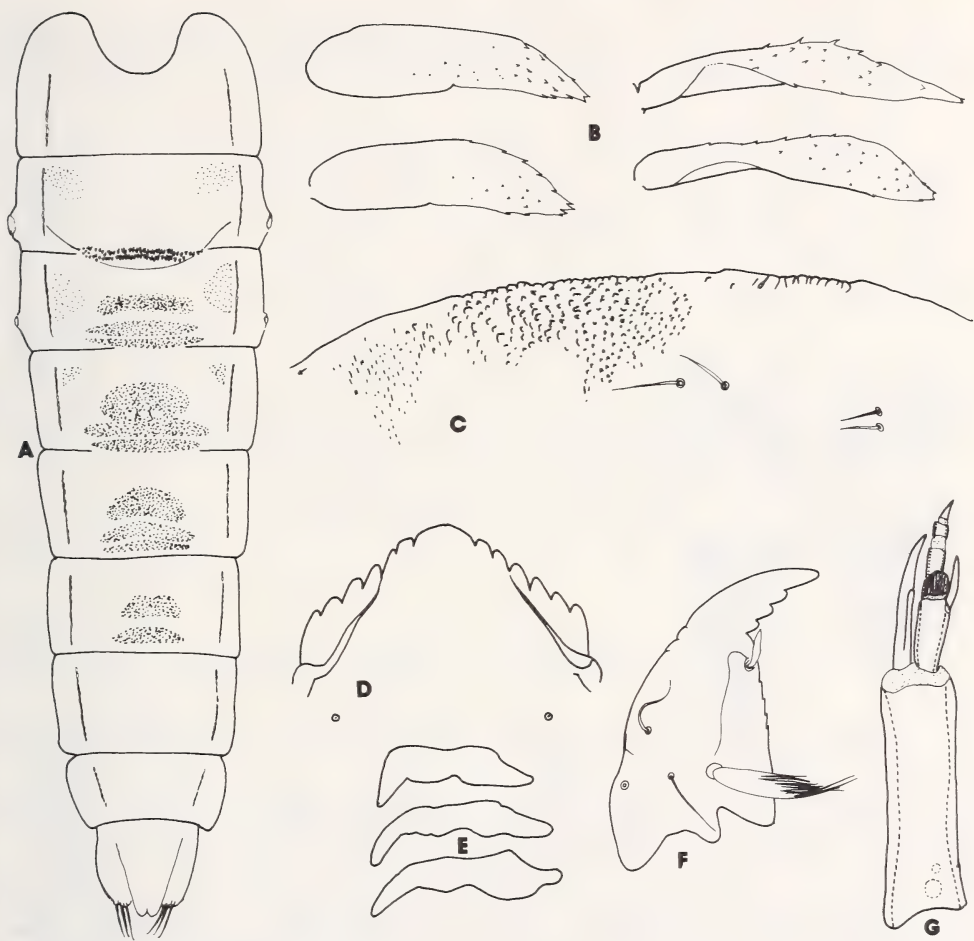


FIG. 17. *Cricotopus bicinctus* (Meigen), pupa A-C, larva D-G. A, ornamentation of pupal exuvia, dorsal view. B, prothoracic horn, variation. C, ornamentation along eclosion line and dorsocentral setae. D, hypostomium, ventral view. E, premandible, variation. F, mandible. G, antenna.

of its mandible and the broad, median tooth of its hypostomium. Recently, Oliver (1977) described a new and closely related species, *C. mackenziensis* with small, frontal tubercles present on the adults. The inner edge of the gonostylus of the male is well developed, two characters absent in *C. bicinctus*. In the pupa, the dorsocentral setae are thicker than those of *C. bicinctus*, black, and placed differently. The larva has a smaller mandible.

Distribution. Reported in CANADA from Yukon to Newfoundland (Oliver 1977; Rosenberg & Wiens 1976; Rosenberg *et al.* 1977) and in United States from CALIFORNIA (Ali & Mulla 1976; Clement *et al.* 1977a,b) to NEW YORK (Johannsen 1905; Sublette & Sublette 1965).

Material examined. On slide: ONTARIO Elmira, Salem Creek, 4 ♂♂, 3 ♀♀, 18.V-22.VI.1976; 14 ♂♂, 9 ♀♀, 17.V-11.X.1977. Associated larva-pupa-adult: Elmira, Canagagigue River Lower East, K. Dance, 27.IV.1976 (1 ♂, 1 ♀), 10.IX.1976 (1 ♂), Upper East 21.VII.1976 (1 ♀), 11.IX.1976 (1 ♀). Elmira, Salem Creek, 19.V.1978 (2 ♂♂), 10.X.1976 (1 ♀), 14.X.1976 (1 ♂). Elmira, Canagagigue River, 10.IX.1976 (1 ♂), 21.V.1978 (1 ♂). In alcohol: Elmira, Salem Creek, about 2375 ♂♂ and 2570 ♀♀ from May 1976 to October 1978.

***Cricotopus (Cricotopus) trifascia* Edwards**

Cricotopus trifascia Edwards, 1929:322 (original description, male).

Cricotopus ithacanensis Sublette, 1967b:555 (original description, male). NEW SYNONYM.

Cricotopus sp., Mason, 1968:85; 1973:85 (illustration, larva).

Cricotopus (Cricotopus) trifascia Edw. Hirvenoja, 1973:244 (redescription, key, adults, pupa, larva).

MALE (Fig. 18)

Length. 4.0 (3.5-4.5) mm; thorax 1.3 (1.1-1.5) mm; abdomen 2.7 (2.3-3.1) mm.

Thorax. Shining. Mesonotal bands contrasting sharply with orange, ground colour, infuscated with brown in darker specimens.

Wings. Transparent. Length 2151 (1838-2343) μm , width 709 (606-788) μm . Setae: first axillary sclerite with one seta; remigium 1.2 (1-2); squama 20.1 (15-26); vein R 3.7 (1-6) proximal: R_1 0; R_{4+5} 0. Anal lobe roundly produced.

Legs. Pure white ring on fore tibia with apical, dark-brown band about twice the length of basal, dark band; light ring on mid tibiae white or yellowish, yellowish or pale brown on hind tibiae. Fore tarsi dark brown, mid and hind tarsi brown. Sensilla chaetica 27.1 (16-39) present only on basal 3/7 (1/4-1/2) of hind tarsi 1.

Abdomen. Tergites I, IV yellow, II-III dark brown with anterior 1/6-1/3 and posterior 1/6 yellow, V dark brown with anterior 1/5 yellow and narrow, paler band posteriorly, VI-VIII dark brown, more or less distinctly paler on the anterior 1/5-1/2 and a more or less distinct, paler margin posteriorly. On tergites III-IV median setae not numerous, uniserial; lateral setae numerous and dispersed. Transverse, posterior row of setae not present. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	2.2 (1-4)	12.2 (5-17)
Tergite IV	3.3 (2-4)	13.6 (10-18)

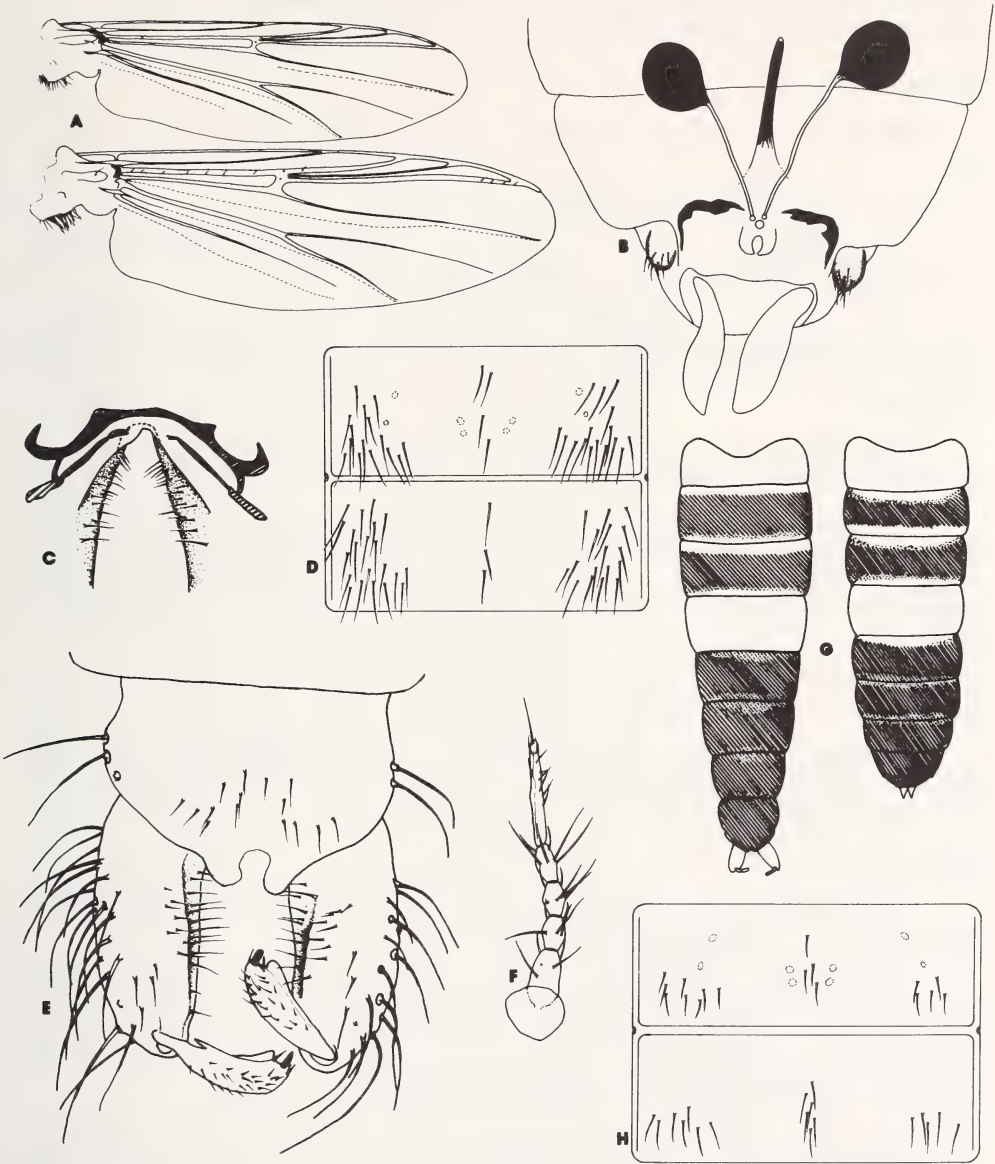


FIG. 18. *Cricotopus trifascia* Edwards, imagines. A, wing, male (upper), female (lower). B, female genitalia, ventral view. C, male hypopygium, ventral view. D, chaetotaxy on abdominal tergites III-IV of the male. E, male hypopygium, dorsal view. F, antenna, female. G, abdominal coloration, male (left), female (right). H, abdominal chaetotaxy of abdominal tergites III-IV of the female.

Hypopygium. Yellow to brownish in some specimens. Length of gonocoxite 259 (226-287) mm, length of gonostylus 112 (104-113) μm . Anal point absent. Posterior margin of tergite IX strongly notched. Basal lobe absent or scarcely indicated. Inner lobe of gonostylus moderately developed.

FEMALE (Fig. 18)

Length. 4.0 (3.7-4.3) mm; thorax 1.4 (1.3-1.5) mm. Abdomen 2.6 (2.4-2.8) mm.

Antenna. Preapical seta present 213 (96-270) μm .

Thorax. Shining. Coloration as in the male but somewhat lighter especially on ventral half of preepisternum II which is pale brown.

Wings. Transparent. Length 2420 (2222-2626) μm , width 893 (788-949) μm . Setae: first axillary sclerite with 1 seta; remigium 1.1 (1-2); squama 23 (18-32); vein R 6.5 (5-9); R_1 0.5 (0-2) proximal; R_{4+5} 3.4 (3-4) distal. Anal lobe rectangular or rounded.

Legs. Coloration as in the male. 35.1 (30-39) sensilla chaetica on basal half of mid tarsi 1 and 46.4 (41-51) on basal half of hind tarsi 1.

Abdomen. Coloration as in the male. Anterior and posterior band on V-VII light yellow rather than pale brown; anterior 1/3-1/2 of VIII often yellow. On tergites III-IV median setae uniserial; lateral setae concentrated in posterior, lateral corners; transverse, posterior row of setae not present. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	2.5 (1-4)	6.7 (3-11)
Tergite IV	4.5 (2-7)	6.0 (4-9)

Genitalia. Cerci white. Spermathecae dark brown, roundish to oval, 102 (87-122) μm long. Spermathecal ducts nearly straight. Lateral sternites of abdominal segment IX well developed.

PUPA (Fig. 19)

Colour: exuvia brownish. Length of the exuvia (mm): 4.6 (4.0-5.2), cephalo-thorax 1.5 (1.3-1.7), abdomen 3.1 (2.6-3.5).

Cephalothorax. Anterior part of notum not granular along the eclosion line or ornamentation weakly indicated. Pronotal horn transparent, almost bare 416 (270-565) μm long, 64 (52-78) μm wide. Prothoracic horn ratio 6.45 (3.44-8.13). Frontal tubercule absent; frontal setae 101 (70-148) μm , slender, located on the frontal plate present above the middle of the base of the antenna.

Abdomen. Length of anal lobe 322 (287-348) μm . Internal, anal seta (2 μm thick, 20 μm long) much smaller than two other, large, anal setae (9-10 μm thick) 317 (270-348) μm long. Pedes spurii B present on abdominal segment II. Last lateral setae on segment III-IV plumose, very robust on V-VIII (125-200 μm . Setae present on abdominal segments I-VIII:

	I	II	III	IV	V	VI	VII	VIII
dorsals	3-4	4	5	5	4	4	4	1
laterals	1	3	4	4	4	4	4	4
ventrals	0	2	4	4	4	4	4	0

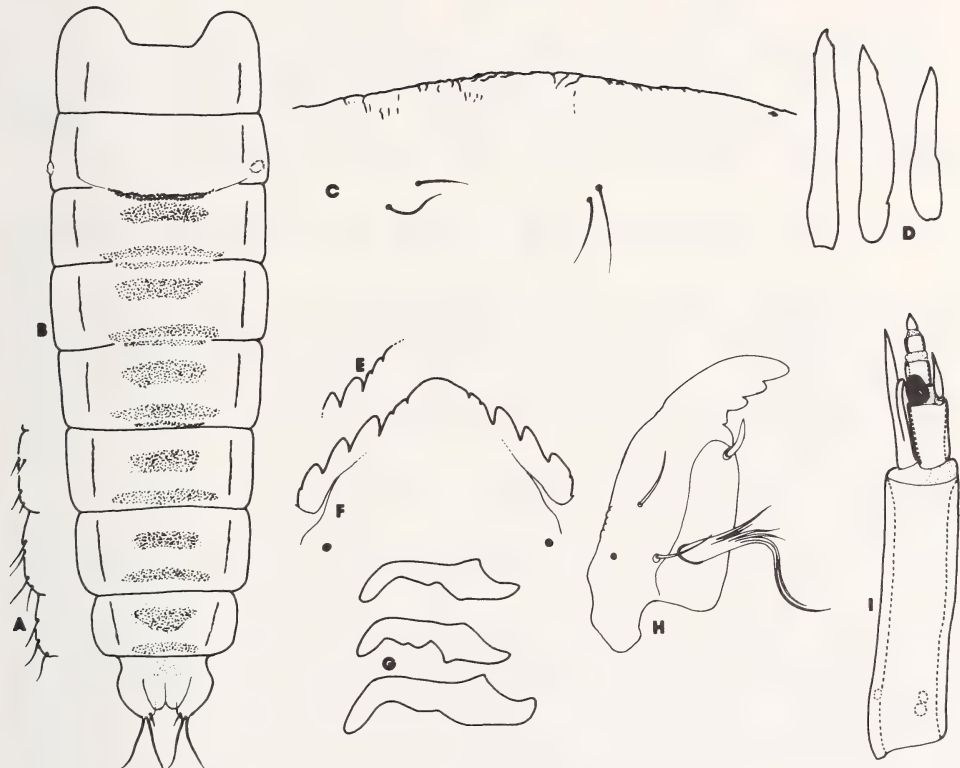


FIG. 19. *Cricotopus trifascia* Edwards, pupa A-D, larva E-I. A, lateral setae on abdominal segments VI-VIII. B, ornamentation of pupal exuvia, dorsal view. C, ornamentation along eclosion line and dorsocentral setae. D, prothoracic horn, variation. E, first lateral teeth, variation. F, hypostomium, ventral view. G, premandible, variation. H, mandible. I, antenna.

Tergites: I bare; II with only a narrow, transverse patch of 113.2 (85-150) recurved spines, biserial, or sometimes with also a very small, spine patch anteriorly; III-V with three, spine patches: anterior patch reniform and well separated from median patch, median and posterior, spine patches narrow, transverse and close to one another; VI-VIII with two, spine patches; anterior patch more or less reniform and separated from posterior, transverse, marginal spine patch.

LARVA (Fig. 19)

Fourth-instar larva (exuvia) 3.5-6.1 mm long. Head capsule brownish, darker laterally and posteriorly. Body greenish.

Antenna 113 (88-127) μm long, 0.66 (0.56-0.81) as long as mandible, 6.46 (5.25-7.38) times as long as wide. Lauterborn's organs large, well developed, antennal blade extending to the base or beyond the antennomere 5, accessory seta to the basal 1/3 of antennomere 3, and sensory seta to the base of antennomere 4. Antennal ratio 0.49 (0.39-0.58). Labral setae SI bifurcated. Epipharynx with five chaetulae laterales and two chaetulae basales; pecten with three large setae.

Premandible simple, brown, generally darker apically. Distal part of the mandible black, inner margin smooth, outer edge with several weak crenulations.

Hypostomium, black 167 (150-186) μm wide, 81 (73-93) μm long. Hypostomial ratio 0.49 (0.43-0.55). Median tooth and first two, lateral teeth indistinctly paler than other lateral teeth (apparent only by transmitted light). Median tooth triangular, first and second lateral teeth fused together and about 1/4 the size of the median tooth, lateral teeth 3-5 triangular, decreasing in size, lateral tooth 6 scarcely indicated, lateral tooth sometimes rounded.

Anal gills sausage-shaped. Claws on anterior prolegs and posterior pseudopods brown. Lateral hair-tufts short, 45 (34-68) μm .

Remarks. This is a large striped species with abdominal tergites I and IV yellow, the others dark brown. The male hypopygium is yellowish and distinctive with basal lobe scarcely indicated. Additional distinctive features found in the females are their large size, the abdominal chaetotaxy, the small spermathecae, and the straight, spermathecal ducts. The pupa was the only one bearing two, spine patches on tergites VII-VIII, robust, lateral setae on V-VIII, almost bare prothoracic horn, and very short, inner, anal seta. The larva is very distinctive because of the following characters: the hypostomium is black with the first, second and sixth lateral teeth very small giving to the hypostomium the appearance of a large, median tooth bordered by three, lateral teeth; the first, antennal segment is very long and the mandible is more elongated than in other species.

The specimens from Salem Creek, as well as the type specimen from New York, correspond with the previously known European species, *C. trifascia* Edwards, and the name *Cricotopus ithacanensis* Sublette is placed in synonymy. The species is reported for the first time in Ontario.

Distribution. Reported from EUROPE (Hirvenoja 1973), and in North America sub *Cricotopus ithacanensis* Sublette from NEW YORK (Sublette 1967b).

Material examined. On slide: ONTARIO, Elmira, Salem Creek 7 ♂♂, 22.V-16.X.1976; 13 ♀♀, 10 ♀♀, 1.V-12.IX.1977; 1 ♂, 2 ♀♀, 23.V-1.VI.1978. Associated larva-pupa-adults: Elmira, Canagagigue River Upper East, K. Dance. 13.VIII.1976 (1 ♀). Canagagigue River 21.V.1978 (1 ♂). L. LeSage. Salem Creek

20.V.1978 (1 ♀), 11.X.1976 (1 ♀), 14.X.1976 (1 ♀), 18.X.1976 (1 ♂); Conestogo, Conestogo River, 17.V.1978 (1 ♂), 19.V.1978 (2 ♂ ♂), 20.V.1978 (1 ♂). In alcohol: Elmira, Salem Creek, about 785 ♂ ♂, 745 ♀ ♀ from May 1976 to October 1978. Originally described as *Cricotopus ithacanensis* Sublette. Holotype male, Ithaca, New York, May 12, 1936; sub-slide S64-1263 located in the Cornell University Collection, ITHACA.

***Cricotopus (Isocladius) sylvestris* (Fabricius)**

Tipula sylvestris Fabricius, 1794:252 (original description, adult).

Cricotopus sylvestris (Fabricius), Malloch, 1915:505 (redescription, key, male); Walley, 1928:22 (key, adult); Johannsen, 1937:52 (key, pupa, larva); Johannsen & Townes, 1952:17 (key, adults); Roback, 1957b:69 (key, pupa, larva); Darby, 1962:62 (description pupa, larva).

Cricotopus (Isocladius) sylvestris (Fab.) Hirvenoja, 1973:277 (redescription, key, adults, pupa, larva); Saether, 1977:116 (illustration, female genitalia).

MALE (Fig. 20)

Length. 3.7 (3.1-4.3) mm; thorax 1.2 (1.1-1.2) mm; abdomen 2.5 (2.0-3.1 mm).

Thorax. Mesonotal bands sharply contrasting on the yellow ground colour, which is sometimes lightly infuscated with brown in front of scutellum.

Wings. Milky transparent. Length 1772 (1636-1980) μm , width 568 (505-626) μm . Setae: first axillary sclerite with one seta; remigium one; squama 16 (13-20); vein R 4.6 (3-7 proximal; R_1 0; R_{4+5} 0. Anal lobe moderately produced.

Legs. All tibiae with white ring; basal, brown band larger than apical. Fore tarsi dark brown distinctly darker than mid and hind tarsi; all tarsi 1-2 and basal 3/4 of mid and hind tarsi 3 generally whitish, apical 1/4 of all tarsi 3, and tarsi 4-5 light brown. 17.2 (15-22) sensilla chaetica on basal half of hind tarsi 1. Small pulvilli present.

Abdomen. Tergite I yellow, II-III dark brown with a distinct 1/4 anterior yellow marginal band, IV almost yellow with a round spot in the middle, V dark brown with an anterior yellow marginal band, VI dark brown with pale coloration on posterior 1/3, VII generally yellowish more or less infuscated with brown on anterior 1/3. On tergites III-IV median setae very robust (4-6 μm thick), uniserial; lateral setae weaker (2 μm thick), biserial, triserial sometimes, widely separate; transverse posterior row of setae not present. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	4.4 (3-6)	8.8 (7-11)
Tergite IV	4.4 (3-6)	13.2 (8-16)

Hypopygium. White. Length of gonocoxite 213 (200-235) μm , length of gonostylus 97 (70-104) μm . Anal point absent. Basal lobe uniramous, directed obliquely backwards, with long, marginal setae. Inner edge of gonostylus well developed, maximum at the base of apical spine which is strong and black.

FEMALE (Fig. 20)

Length. 3.1 (2.4-3.4) mm; thorax 1.2 (0.9-1.3) mm. abdomen 1.9 (1.5-2.1 mm. BR 1.65 (1.56-1.85).

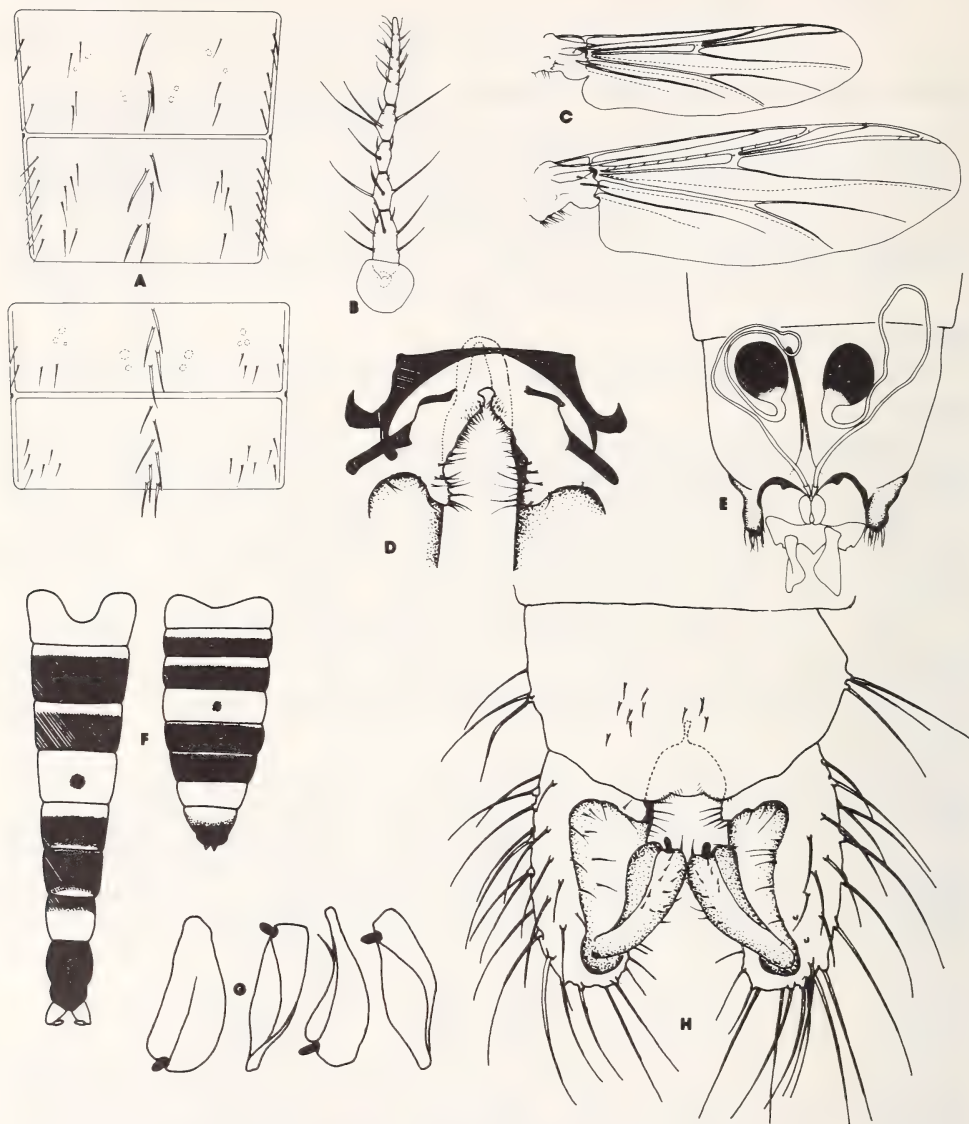


FIG. 20. *Cricotopus sylvestris* (Fabricius), imagines. A, chaetotaxy on abdominal tergites III-IV of the male (upper) and the female (lower). B, antenna, female. C, wing, male (upper), female (lower). D, male hypopygium, ventral view. E, female genitalia, ventral view. F, abdominal coloration, male (left), female (right). G, male gonostylus, variation. H, male hypopygium, dorsal view.

Antenna. Preapical seta absent.

Thorax. Coloration as in the male, but lighter laterally and ventrally.

Wings. Milky, transparent. Length 1880 (1495-2202) μm , width 695 (545-808) μm . Setae: first axillary sclerite with one seta; remigium 1.1 (1-2); squama 16.6 (11-22). vein R 10.2 (8-13); R_1 6 (4-9); R_{4+5} 2.6 (1-6) distal. Anal lobe obtuse, not produced.

Legs. Coloration as in the male. There are 41.4 (30-49) sensilla chaetica on basal 9/10 of mid tarsi 1 and 42.3 (34-51) on basal 9/10 of hind tarsi 1. Small pulvilli present.

Abdomen. Coloration as in the male in general; segment II-III, V-VI with a light anterior margin however, and VII generally completely yellow or white. On tergites III-IV, median setae very robust (4-5 μm) uniserial; lateral setae weaker (2-3 μm) more or less distinctly bi- or triserial; transverse row of setae not present. Tergal chaetotaxy:

	median setae	lateral setae
Tergite III	4.8 (2-7)	4.1 (2-5)
Tergite IV	5.2 (2-8)	5.2 (2-7)

Genitalia. Cerci white. Spermathecae dark brown, roundish 82 (70-104) μm wide, 92 (78-113) μm long, seminal capsule large, paler. Spermathecal ducts strongly looped anteriorly. Lateral sternites of abdominal segment IX well developed.

PUPA (Fig. 21)

(n=2). Colour. Exuvia transparent with a pale yellowish tint. Length of the exuvia (mm) 1.5-2.1, cephalothorax 1.0-1.5, abdomen 0.4-0.6.

Cephalothorax. Largely and strongly granular along the eclosion line. Pronotal horn cylindrical, rounded apically not covered with spinules 191-261 μm long, 17-18 μm wide. Pothoracic horn ratio 11.00-14.28. Frontal tubercule absent. Frontal setae 4-5 μm thick, 227-239 μm long, located on the frontal plate above the middle of the base of the antenna.

Abdomen. Anal lobe length 270-287 μm ; length of the longest anal seta 104-113 μm . Pedes spurii B weak, present on segment II. Setae present on segments I-VIII:

	I	II	III	IV	V	VI	VII	VIII
dorsals	3	4	4	5	5	5	5	2
laterals	1	3	3	3	3	3	3	4
ventrals	1	3	3	4	5	5	5	2

Tergites: I bare, II completely covered by rough shagreen becoming stronger caudad, transverse row of 66, recurved spines: III-V completely covered by rough shagreen mixed with median, spine patch; spine patch along the posterior margin elongated, transverse, and fused more or less distinctly with median, spine patch; VI covered by a large, median, spine patch gradually mixed with shagreen laterally; VII-VIII with shagreen laterally and basally.

LARVA (Fig. 21)

(n=2). Fourth-instar larva (exuvia) 4.0-61 mm long. Head capsule brownish somewhat darker laterally and posteriorly.

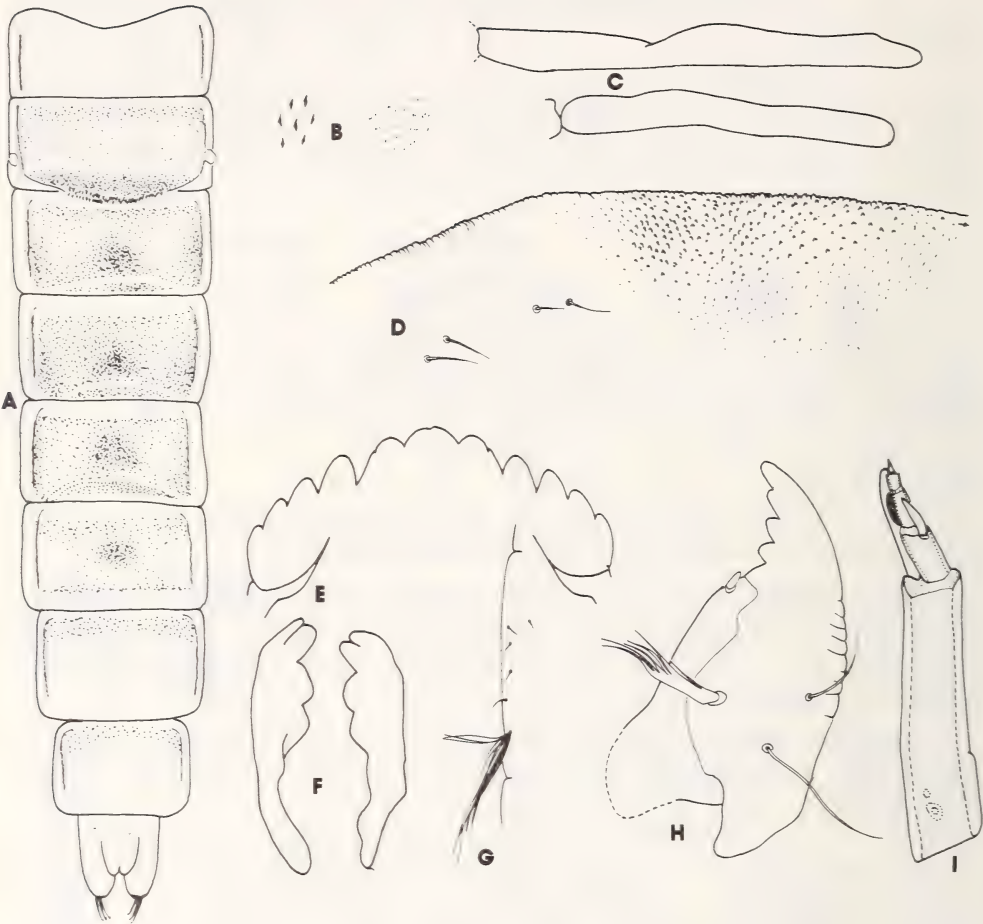


FIG. 21. *Cricotopus sylvestris* (Fabricius), pupa A-D, larva E-I. A, ornamentation of pupal exuvia, dorsal view. B, detail of ornamentation of left, spine patch, on right, shagreen. C, prothoracic horn, variation. D, ornamentation along eclosion line and dorsocentral setae. E, hypostomium, ventral view. F, premandible, variation. G, lateral setae on abdominal segment IV. H, mandible. I, antenna.

Antenna 93-100 μm long, 0.52-0.71 as long as mandible, 5.47-5.50 times as long as wide. Lauterborn's organs large, antennal blade extending to the apex of antennomere 4, accessory seta to basal 1/3 of antennomere 3, and sensory seta to 3/4 of antennomere 3. Antennal ratio 0.47-0.61.

Labral setae SI bifurcated. Epipharynx with two chaetulae laterales and two chaetulae basales; pecten with three large scale-like setae fused at base.

Premandible with two, apical teeth; premandibular brush absent. Distal part of the mandible dark brown to black, inner margin smooth, dorsal edge strongly wrinkled with numerous crenulations. Seta subdentalis 7 μm , short, not reaching the base of the last tooth; setal interna 5 μm finely plumose.

Hypostomium 145-150 μm wide, 61-64 μm long. Hypostomial ratio 0.41-0.44. Median tooth and the first two lateral teeth paler than the remaining teeth. Median tooth convex more or less distinctly notched in the middle. First and second, lateral teeth fused. Lateral teeth 3-6 decreasing regularly in size.

Anal gills sausage-shaped, distally rounded. Pseudopoda claws brown, darker than the pale, brown, anterior, proleg claws. Lateral hair-tufts on abdominal segments I-VI very long 295-318 μm .

Remarks. The large, brightly coloured, striped adults are distinctive with their abdominal segments I, and almost IV and VII yellow and with their abdominal setae uniserial distinctly more robust than lateral setae. Only the larva of this species bears two, apical teeth on the premandible and has very long hair-tufts on abdominal segments I-VI. The pupa is unique with bare cylindrical prothoracic horns, and ornamentation entirely covering tergites II-IV.

The status of specimens from Salem Creek is difficult to establish as they have characteristics shared by *C. trifasciatus* (Meigen), *C. sylvestris* (Fabricus) and *C. remus* Sublette. The adults key out to the small form of *C. trifasciatus* in Hirvenoja (1973), but they bear also a spatulate gonostylus and posterior notopleurals (prealars) of unequal size as in *C. remus* (Sublette 1964). In the pupa, the frontal setae which are 3.5 μm thick, and the small pedes spurii B, present on abdominal segment II, place our specimens in *C. sylvestris*. The apical teeth on the claws of the anterior prolegs of the larva seem about the same size as the lateral teeth, as in the larva of *C. sylvestris*. These features were also observed in the immatures of the paratype of *C. remus* examined; however, the prothoracic horn of its pupa was slightly darker than the rest of the tegument and weak pedes spurii B were present on abdominal tergite III in addition to tergite II. The adults of the *sylvestris*-group are difficult to separate and are extremely variable in their colour pattern. The characters of the immatures, more constant than those found in the imago, refer our specimens either to *C. sylvestris* or *C. remus*. However, the first name is used here as it reflects the wide distribution of the species. Future studies throughout North America will probably show that specimens referred to *C. remus* can be considered as members of this circumboreal species and that the small differences observed can be attributed to geographical variations.

Distribution. Reported from EUROPE (Hirvenoja 1973); and in North America from CALIFORNIA (Ali & Mulla 1976; Clement *et al.* 1977a,b; Grodhaus 1963, 1968) to NEW YORK (Johannsen 1937; Johannsent & Townes 1952).

Material examined. On slide: ONTARIO: Elmira, Salem Creek, 5 ♂♂, 2 ♀♀, 10.VI-4.VIII.1976; 1 ♂, 9 ♀♀, 24.V-29.VI.1977. Waterloo, at blacklight in a field, 8 ♂♂, 5 ♀♀, 21.VI-30.VI.1976. Conestogo, Conestogo River, 2 ♂♂, 1 ♀,

23-27.V.1978. Associated larva-pupa-adult: Elmira, Canagagigue River Upper East, K. Dance, 12.VII.1976 (1 ♀), 16.VIII.1976 (1 ♀). In alcohol: Elmira, Salem Creek, about 25 ♂ ♂ and 150 ♀ ♀ from May 1976 to September 1978.

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III. NOTE

EFFECTS OF NOSEMA FUMIFERANAE (MICROSPORIDA) ON REARING STOCK OF SPRUCE BUDWORM, CHORISTONEURA FUMIFERANA (LEPIDOPTERA: TORTRICIDAE)

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Laboratory rearings of the spruce budworm are often chronically infected with the microsporidium *Nosema fumiferanae*. Infection of the spruce budworm by *N. fumiferanae* retards both larval and pupal development and reduces pupal weight, adult fecundity and longevity (Thomson 1958; Wilson 1977). Depending on the level of infection, the presence of this parasite could cause problems in rearings and interfere with other test pathogens. There is some indication that the ingredients of the synthetic diet on which spruce budworm are reared may in some way help the host to mitigate some of the debilitating effects of this microsporidium (Grisdale 1980). McMorran (1965) showed that spruce budworm reared on a synthetic diet had a higher survival rate, developed faster, were heavier, and laid more eggs than did larvae fed frozen balsam fir buds. The present study was conducted to determine the effect of feeding synthetic diet on the vigor of microsporidian-infected hosts.

Insects used in this study (newly emerged from hibernacula) were initially reared for 12 days in the quarantine facilities of the Institute using the method described by Grisdale (1970). One group of larvae were naturally infected (90-95%) with *N. fumiferanae* and the other was microsporidia-free. After the initial 12 days the spruce budworms were placed in 28.4 ml plastic cups (6 larvae per cup), filled $\frac{3}{4}$ with a synthetic diet (McMorran 1965). The larvae were maintained in the laboratory at room temperature (21-23°C) and 40-60% relative humidity. The cups were checked every other day to determine larval mortality and to ensure that the diet surface was free of fungal contamination.

At the onset of pupation, the cups were checked daily and all pupae were removed, sexed and weighed within 24 hr of pupation. Adults used for oviposition were paired and placed in 178-ml paper cups containing a balsam fir twig. Only eggs from fertile matings were counted. Larval and pupal mortality, days as pupae and adults, pupal weights, and numbers of eggs laid per female were recorded.

The results for this study are given in Table 1. The mean pupal weight of infected female pupae was significantly lower than that of the non-infected group. Mortality of larvae and pupae was not affected significantly by infection. Longevity of infected and non-infected adults differed slightly but was lower in the infected group. The number of eggs laid by the infected group was about 10% less than by the non-infected group and the rate of hatch was lower.

Although Wilson (1978) reported no significant difference in microsporidian spore production for budworm reared on synthetic diet, balsam fir or spruce and suggested that the ingredients of the synthetic diet had no effect on the ability of the parasite to multiply, it does appear from the present study that the nutritional value of the diet does allow the host to better cope with the parasite. However, higher initial levels of infection may increase the ill effects of the parasite.

TABLE I. The effect of infection by *Nosema fumiferanae* on the biology of the spruce budworm.

Biology		Treatment	
		Non-infected	Infected
Per cent mortality	larvae	6.0 (233) ^a	9.7 (226) ^a
	pupae	5.5 (219)	4.4 (204)
Mean pupal weight (mg/insect)	male	71.4 (115)	67.7 (98)
	female	106.5 (85)	96.5 ^b (94)
Mean pupal stadium (days)	male	7.5 (115)	7.7 (98)
	female	7.7 (85)	7.5 (94)
Mean imaginal stadium (days)	male	9.6 (114)	8.3 (95)
	female	12.1 (82)	11.8 (78)
Eggs/female	mean	173 (21)	157 (25)
	range	60-259	34-245
Per cent hatch		85.7	79.5

^a Numbers in parentheses are the sample sizes.^b Significantly different from the non-infected check ($p \leq 0.01$).

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I. THE SOCIETY

IN MEMORIAM

E. Melville DuPorte (1891-1981), an esteemed colleague and former member of our society, died on 31 July 1981. An obituary written by Dr. D. K. McE. Kevan was published in the Bulletin of the Entomological Society of Canada 13(4): 154-156.

PRESIDENT'S PRIZE — 1981

Tarlochan S. Dhadialla, Department of Biology, Queen's University, won the "President's Prize" in 1981 for the best student paper presented at the annual meeting in October at Queen's University, Kingston. His paper, entitled "Development of Sex-Limited Competence for Juvenile Hormone Induced Vitellogenesis in *Locusta migratoria*", was judged the best of eleven in the competition.

T. S. Dhadialla was born in Nairobi, Kenya in 1948. He got his first B.Sc. degree in Biology from the Punjab University, India in 1968 and a second one in Zoology and Chemistry from the University of East Africa, Nairobi, in 1970. In 1977, he was awarded a M.Sc. degree in Entomology at the Nairobi University. He is at present on a study leave from the International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, to do his Ph.D. in the Department of Biology, Queen's University. His research, under the supervision of Professor G. R. Wyatt, is on the mode of action of juvenile hormone in regulating the production of vitellogenin (yolk precursor protein) in the fat bodies of *Locusta migratoria*. He has found that in nymphal locusts, vitellogenin synthesis can be induced in both sexes by a JH analog, whereas the normal female-limited response to the hormone develops at metamorphosis. At present, he is using organ culture of fat body and recombinant DNA technology to study the synthesis and stability of messenger RNA for vitellogenin in locust fat body, as influenced by JH.

In the past Mr. Dhadialla has been awarded an International Atomic Energy Agency (Vienna) fellowship to learn radioisotope techniques applicable in Entomology at the Institute for the Application of Radioisotopes in Agriculture, Wageningen, The Netherlands. He holds an ICIPE fellowship for his Ph.D. program.

ENTOMOLOGISTS AVAILABLE

The Employment Committee of the Entomological Society of Canada has published the 1982 edition of the booklet containing the résumés of members who are looking for employment. A copy of this booklet has been sent to all present employers of entomologists in Canada, including Agriculture Canada and Environment Canada research stations, as well as the chairmen of all university biology departments. If you do not have access to this publication, a copy may be obtained from:

The Chairman
Employment Committee (Entomological Society of Canada)
Department of Environmental Biology
University of Guelph
Guelph, Ontario
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FELLOWS OF THE ENTOMOLOGICAL SOCIETY OF ONTARIO

	Elected
Anthony William Aldridge Brown	1969
Robert Glen	1969
Walter Edward Heming	1981
George Pearson Holland	1971
George Francis Manson	1968
David Harvey Pengelly	1981
Cecil Raymond Twinn	1963

MICRO-ORGANISMS AS FOOD FOR THE ONION MAGGOT, *DELIA* (=HYLEMYA) *ANTIQUA* (DIPTERA: ANTHOMYIIDAE)

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Abstract

Proc. ent. Soc. Ont. 112: 1-5 (1981)

The correlation between pharyngeal ridges in certain Diptera and microbial grazing is discussed. Scanning electron micrographs of pharyngeal ridges in the onion maggot (*Delia antiqua* Meigen) are provided, and it is hypothesized that the onion maggot is a microbe grazer. Onion maggot larvae were reared on onion either sterilized or inoculated with bacteria. Results indicate that bacteria or their products play a major role in the development and survival of onion maggots.

Introduction

Micro-organisms can accelerate the growth of maggots on artificial medium (Friend *et al.* 1959) and female onion flies are attracted to decomposing onion in the field (Dindonis and Miller 1980). The association of onion maggots and microbial decay has often been observed (Smith and Dickerson 1907; Johnson 1930). However, it has not been demonstrated that onion maggots selectively feed on micro-organisms or are dependent on them in nature.

Keilin (1912) observed that the floor of the pharynx in known saprophagous muscoid larvae is marked with a series of longitudinal ridges, and that these ridges are absent from forms feeding on living material. Muirhead-Thompson (1937) further substantiated this correlation between pharyngeal ridges and a saprophagous habit, but it was not until Dowding's (1967) study that the function and significance of pharyngeal ridges was shown. She showed that they constitute a filter by which some Diptera concentrate micro-organisms for ingestion. Pharyngeal ridges function by dividing the lumen of the pharynx into the main lumen dorsally and 8 channels ventrally. The food enters the main lumen and then is pressed between the roof of the pharynx and the pharyngeal ridges, thus concentrating the particulate matter above the ridges and expelling the fluid anteriorly through the lumina of the ventral channels. The bolus of micro-organisms thus formed is moved posteriorly into the oesophagus. Dowding (1967) and Roberts (1971) provided detailed analyses of this process and described the mouthparts of *Calliphora vicina* (Meigen). The objective of this project was to determine whether or not pharyngeal ridges were present in larvae of the onion maggot and if so to determine the importance of microbial grazing in this species.

Materials and Methods

Third-instar larvae were dried in a critical-point drier, mounted on a stub, then dissected to expose the interior of the pharynx. These preparations were coated with gold-palladium then photographed at 10 kv in an ETEC Autoscan scanning electron microscope. Maggots used in all experiments were obtained from a culture maintained by the Department of Environmental Biology, University of Guelph. Eggs were sterilized using the method of Friend *et al.* (1959).

Sterile onion was obtained by aseptically dissecting onions to isolate slices of the inner layers. These slices were tested for sterility by placing them in sterile tryptic soy broth for 48h at 30°C, then examining the broth for bacterial growth.

Since only 33 of 175 slices (19%) from 8 onions were contaminated, aseptic dissection was accepted as a satisfactory method for obtaining sterile tissue. Slices treated as above (hereafter called tested slices) were rinsed twice in sterile, distilled water and then used in the following experiments.

One hundred and nine combinations of aseptically dissected onion slices and onion maggot eggs were used in six treatments as follows:

- 1) One sterile egg placed on each of 20 untested (sterility not tested by incubation in broth) slices.
- 2) One sterile egg placed on each of 18 tested slices.
- 3) One non-sterilized egg added to each of 20 tested slices.
- 4) One sterile egg added to each of 20 tested slices, which had been inoculated with a bacterial colony isolated from a maggot-infested onion.
- 5) One sterile egg added to each of 21 tested slices, which had been inoculated with bacteria from *D. antiqua* egg surfaces.
- 6) One sterile egg added to each of 10 tested slices inoculated with bacteria from broth isolates.

Each treatment was incubated at 25°C and 16hL:8hD and was observed daily for hatching, molting, pupation and emergence. The onion slices were re-tested for sterility at the end of the experiment, and the data from accidentally contaminated replicates discarded. Three replicates of treatment 2 were found to be contaminated. Fresh slices were added to treatments when the originals were depleted by larval feeding. Adults that emerged were caged with food, water and a dish for oviposition to determine if viable eggs would be produced.

Chi-squared contingency tables were used to assess differences among treatments in the number of first-instar larvae that survived to the adult stage (unless some other stage was indicated). Student's *t* tables were used to calculate the 95% confidence intervals for mean time spent in each instar for each treatment.

Results and Discussion

Figures 1-4 show the pharyngeal ridges of the onion maggot. To our knowledge these are the first scanning electron micrographs of pharyngeal ridges, and the first observation of their occurrence in onion maggots. This observation suggests that onion maggots are adapted to filter and concentrate microbe-sized particles.

Maggots reared on sterile onion developed more slowly and died at an earlier stage than those on inoculated onion (Table I).

The proportion of first-instar larvae reaching the adult stage differed among treatments ($P < .001$). The number of adults produced on onion inoculated with either onion, egg or with both isolates were not different from each other ($P < 0.4$). These data were pooled and the pooled data were different from either of the completely sterile treatments (1 and 2) ($P < .005$ and $P < 0.01$ respectively). This indicates that *D. antiqua* larvae develop more successfully on inoculated onion than on sterile onion. Adults reared from inoculated onion produced a second generation under standard conditions.

In treatment 3 (sterile onion but non-sterilized eggs) a lower proportion of first-instar larvae reached the adult stage than in the pooled inoculated treatment ($P < 0.1$). On the other hand, more larvae in treatment 3 reached the third

TABLE I. The effects of bacteria on developmental time and per cent survival of *Delia antiqua* reared on onion

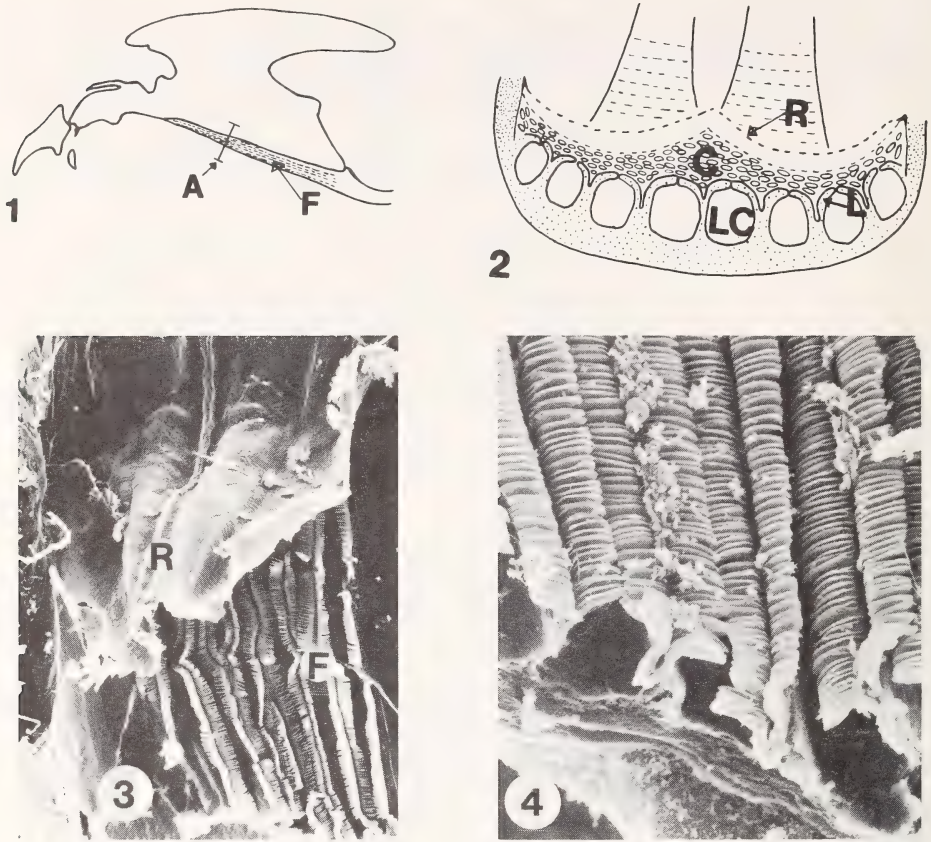
Treatment	Eggs	Onions	Number		Days spent in life stage $\bar{x} \pm SE$				Adults	
			Eggs	1st-instar larvae	1st-instar larvae	2nd-instar larvae	3rd-instar larvae	Pupae	Number	% total
1	Sterile	Untested ¹	20	17	13	—	—	—	0	0%
2	Sterile	Sterile	15	11	9.4 $\pm$ 0.9	9.7	16	—	0	0%
3	Non-sterile	Sterile	20	10	3.9 $\pm$ 1.1	4.0 $\pm$ 1.0	12.5	13	1	10%
4	Sterile	Inoc./onion ² isolate	20	15	4.2 $\pm$ 0.8	3.0 $\pm$ 0.6	12.6 $\pm$ 1.1	13.3 $\pm$ 1.7	7	47%
5	Sterile	Inoc./egg ³ isolate	21	17	3.9 $\pm$ 0.5	3.0 $\pm$ 0.4	13.1 $\pm$ 1.1	13.2 $\pm$ 0.6	5	29%
6	Sterile	Inoc.both ⁴ isolates	10	9	4.5 $\pm$ 1.0	3.7 $\pm$ 0.6	11.6 $\pm$ 1.7	13.8 $\pm$ 0.6	5	55%

¹Aseptically dissected but sterility not tested.

²Sterile, tested onion inoculated with bacteria isolated from *D. antiqua*-infested onion.

³Sterile, tested onion inoculated with bacteria isolated from *D. antiqua* egg surface.

⁴Sterile, tested onion inoculated with both isolates.



FIGS. 1-4. Onion maggot mouthparts. 1, cephalopharyngeal skeleton showing the pharyngeal floor. The transverse section shown in 2 is represented by (A). 2, transverse section of pharynx showing relationship between the roof of the pharynx, the contents, and the longitudinal ridges. 3, dorsal view of pharynx with the roof of the pharynx folded back to expose the pharyngeal floor. 4, transverse section through the pharyngeal floor showing the structure of the pharyngeal ridges and the lumina formed beneath them. Abbreviations: R, roof of pharynx; C, contents of pharynx; L, lamellae of longitudinal pharyngeal ridges; LC, lumina of the ventral channels between pharyngeal ridges; F, floor of pharynx.

instar than in the totally sterile treatment 1 ($P < 0.05$). This indicates that at least some eggs carry an inoculum of micro-organisms beneficial to larval development.

Treatment 2 (sterile eggs on sterile onion) differed from treatment 1 only in that a tested onion (an onion that had been tested with broth) was used in treatment 2. No normal pupae were produced on either treatment; however, more larvae developed to the third instar ($P < 0.05$) in treatment 2 than in treatment 1. This indicates that the residual broth may have contributed to larval development.

In conclusion, it appears that the onion maggot requires some nutrient(s) not present on sterile onion tissue. Since it is morphologically adapted to grazing on micro-organisms, the onion maggot is probably dependant on micro-organisms as a source of these nutrients in nature.

Acknowledgments

We acknowledge Dr. C. T. Corke of the Department of Environmental Biology, University of Guelph, for his encouragement and support.

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**CONTROL OF THE OBLIQUEBANDED LEAFROLLER,
CHORISTONEURA ROSACEANA
(LEPIDOPTERA: TORTRICIDAE), ON PEACHES IN ONTARIO**

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Abstract

Proc. ent. Soc. Ont. 112: 7-12 (1981)

In the Niagara Peninsula, the obliquebanded leafroller, *Choristoneura rosaceana*, is a sporadic pest of early-season peach cultivars. Infestations were controlled with a special spray of phosmet or azinphosmethyl, timed to coincide with hatch of 1st-instar larvae, 9-12 days after an initial increase in adults in pheromone traps, followed by a regularly-timed spray for oriental fruit moth.

Introduction

The obliquebanded leafroller (OBLR), *Choristoneura rosaceana* (Harris), is a widely distributed native species which has become a sporadic pest of apples, pears and peaches in many parts of southern Ontario. The life cycle of the OBLR has been described by Chapman and Lienck (1971). Reissig (1978) has outlined a strategy for control of OBLR on apples.

Infestations on peach in the Niagara peninsula and other peach growing areas of Ontario are not widespread. Larvae do not feed extensively on foliage but feed on the surface of the fruit. They prefer peaches with open split pits where they feed around the open stem and often move down into the fleshy areas around the pit. Early-season cultivars (those harvested in July), such as Earlired, Candor, Harbinger and Sunhaven, can be extensively injured. Peaches with split pits find a ready market in the early season although at reduced prices. Where the opening at the stem end is narrow, OBLR larvae cannot be detected and peaches containing late-instar larvae up to 4 cm in length may be included in shipments to retail markets. This paper reports on a control strategy for OBLR on peach.

Methods

Laboratory bioassay. OBLR larvae collected in 1977 from 2 commercial orchards were maintained continuously on fava bean (*Vicia faba* L.) in a greenhouse for 2-5 generations before use. Moths held in large polyethylene bags (44 x 56 cm) deposited egg masses on the surface of the bags. Egg masses were gently washed from the surface and held on moist filter paper at 20°C and 70% RH.

For bioassay, lots of 10 larvae < 24 h old were placed, using a small brush, on a 7-cm Whatman No. 1 filter paper in a 9-cm glass petri dish. Larvae were immobilized before treatment by placing the petri dishes on trays of ice. Insecticides (technical grade) were applied in 5 ml acetone to OBLR larvae with a Potter Spray Tower. A 13-second application time was followed by a 5-second settling period; air pressure was maintained at 150 mm Hg. Five concentrations of each insecticide were used, each replicated 10 times with 50 larvae. After treatment, larvae were shaken onto a clean 9-cm plastic petri dish lined with a

Whatman No. 1 filter paper. Lids of these dishes were coated with paraffin wax to prevent escape. Mortality counts were made after 2 h in a room at $22 \pm 1^\circ\text{C}$ and 60% RH. Insects were considered dead if incapable of co-ordinated movement.

Monitoring leafroller moths. Flight of male moths was monitored on the Niagara peninsula with Pherocon II® traps baited with OBLR pheromone (Zoecon Corp., Palo Alto, Calif.). Traps (5/site) were placed around the orchard in trees or shrubs such as dogwood, elm or maple. Traps were hung ca. 2 m from the ground and at least 30 m apart. Traps were checked twice weekly and all captured moths recorded and removed.

Field tests of insecticides against larvae. To assess the effectiveness of selected insecticides against field populations, chemicals were applied at various times during the development of the first generation in 1977 and 1978. Insecticide applications were timed to coincide with hatch of 1st-instar larvae by reference to numbers of moths caught in traps and insectary records on duration of the egg stage. In 1977, phosmet (Imidan 50 WP) sprays at 1.1 kg A.I./ha and 2.1 kg A.I./ha were applied to runoff to 8-tree plots of 10-year-old peach trees cv. Earlired at Niagara-on-the-Lake, Ontario. Sprays were applied on 14 June with a Spraymiser gun and jeep-mounted sprayer at 2067 kPa. A second spray was applied to all plots 29 June. Assessment was by examination of 25 peaches with split pits on 12 July.

In 1978, sprays were applied by the grower to 8-year-old cv. Earlired trees (16/plot) with a Berthoud® sprayer at 500 l/ha. Azinphosmethyl (Guthion 50 WP) at 0.75 kg A.I./ha was applied 28 June, and a second spray with phosmet at 2.0 kg A.I./ha was applied 7 July for control of oriental fruit moth. Assessments were by examination of 25 peaches with split pits on 4 and 11 July and 25 peaches with split pits plus 75 other peaches 19 July.

Results

Laboratory tests. The culture established from the field was susceptible to the commonly used organophosphorus insecticides azinphosmethyl and phosmet (Table I). Permethrin was more toxic to OBLR larvae than either azinphosmethyl or phosmet.

Timing spray application. In 1977, catches in pheromone traps began 30 May with the first sizeable catches on 2 June and peak captures 6 June (Table II). Emergence of moths from the overwintering generation extended until early July. Catches of second-generation moths began about 11 July and continued through most of August and September; the rise to maximum catches was much more gradual than for the first generation. Catches of moths from overwintering larvae over a 3-year

TABLE I. Toxicity of insecticides to first-instar larvae of obliquebanded leafroller in the laboratory

Treatment	LC ₅₀	Fiducial Limits		Equation of Log — Probit Line
		Lower	Upper	
Permethrin	.00058	.00050	.00066	$Y = 2.2X + 3.3$
Azinphosmethyl	.00146	.00130	.00162	$Y = 2.5X + 2.0$
Phosmet	.00642	.00585	.00701	$Y = 3.2X - 0.9$

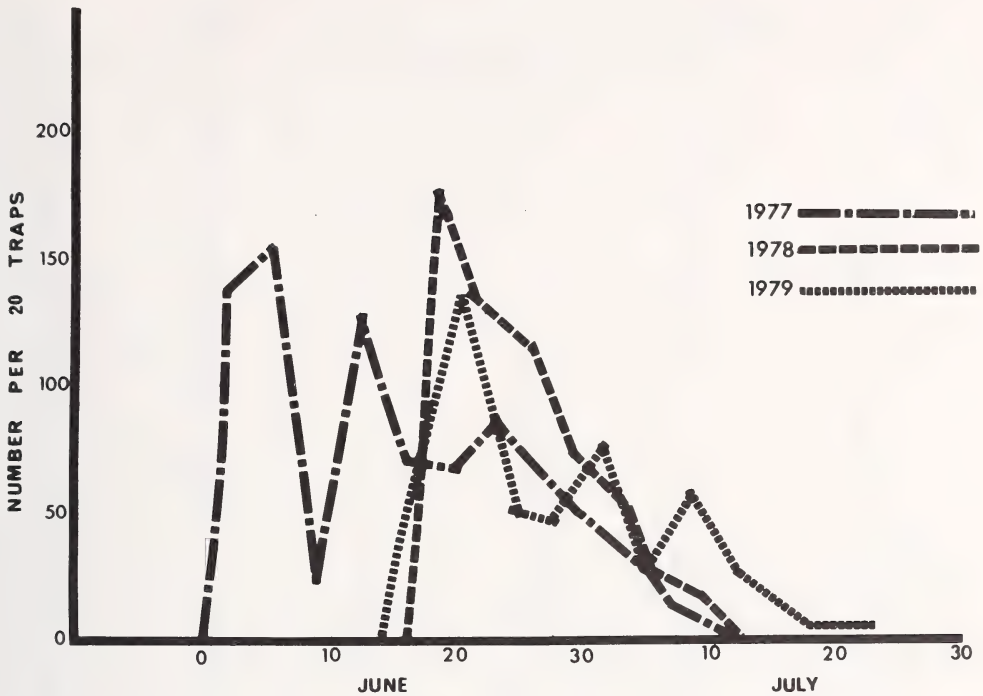


FIG. 1. Captures of 1st-generation obliquebanded leafroller in pheromone traps, Niagara peninsula of Ontario, 1977-1979.

period, 1977-1979, indicate a great variation in the dates of first capture and peak captures in pheromone traps for the 1st generation (Fig. 1). Initial moth captures for the Queenston-1 orchard over the 3-year period occurred on 30 May 1977, 19 June 1978, and 18 June 1979. Initial catches were always followed by a rapid rise in catches.

Studies with the oriental fruit moth (OFM), *Grapholitha molesta* (Busck) (Pree *et al.*, 1980) have shown that it is best to time controls on the basis of total numbers of moths taken from the whole Niagara peninsula, with adjustments in spray times based on climatic differences within the area. For oriental fruit moth, four climatic zones within the Niagara peninsula representing the Queenston, St. Catharines, Beamsville and Vineland growing areas are used. Generally, sprays are required first in the Queenston area. In the early season (late May), there may be 7-10 days difference in spray dates between early- and late-season areas. Catches of moths for 1977-1979 indicate that such differences may also occur for OBLR particularly between the Queenston and Vineland areas (Table II).

In 1977 and 1978, just after the first moths were captured, ca. 50 newly laid

TABLE II. Captures of *C. rosaceana* moths in sex pheromone traps in the Niagara peninsula of Ontario 1977

Date	Queenston-1	Queenston-2	Beamsville	Vineland	Total
May 30	4	2	0	0	6
June 2	62	74	1	0	137
6	48	77	29	1	155
9	11	6	3	3	23
13	41	19	47	17	124
16	16	11	24	19	70
20	7	8	33	19	67
23	6	4	42	31	83
27	5	8	35	16	64
30	1	14	21	15	51
July 4	2	13	16	4	35
7	2	7	5	0	14
11	0	0	2	0	2
14	1	3	1	0	5
18	1	0	1	0	2
21	1	0	2	1	4
25	2	2	5	0	9
28	6	6	0	0	12
Aug. 2	13	7	5	2	27
4	17	5	8	2	32
8	30	26	13	4	73
11	25	34	22	0	81
15	10	18	14	2	44
18	16	18	16	7	57
22	30	9	10	7	56
25	7	15	21	1	44
29	34	31	3	6	74
Sept. 1	12	28	28	18	96
6	35	32	31	4	102
8	15	16	18	4	53
12	8	11	10	9	38
15	11	6	5	4	26
19	5	4	3	3	15

egg masses were placed in an insectary and monitored daily for hatch. Most eggs hatched in 7-10 days. Observation in the laboratory over three generations of ca. 60 pupae of each sex indicated no difference in the rate of development between sexes. The first eggs were produced ca. 2 days after adult eclosion, suggesting that sprays applied 9-12 days after the first sizeable captures in pheromone traps should have maximal effects against 1st-instar larvae.

Field tests of insecticides against larvae. In 1977, the first sprays were applied 14 June, 12 days after the first large increase in captured moths. First egg hatch should have occurred near this date. A second application, largely for oriental fruit moth, was made 29 June. Two applications of phosmet at 2.1 kg A.I./ha controlled 1st-instar larvae (Table III). A single application of phosmet, timed to control oriental fruit moth, was ineffective, clearly indicating the necessity for a specially timed spray to control OBLR. In 1978 infestations were considerably lower than in 1977 and peaches with split pits were considerably fewer. Control was obtained with one application of azinphosmethyl on 28 June, 9 days following

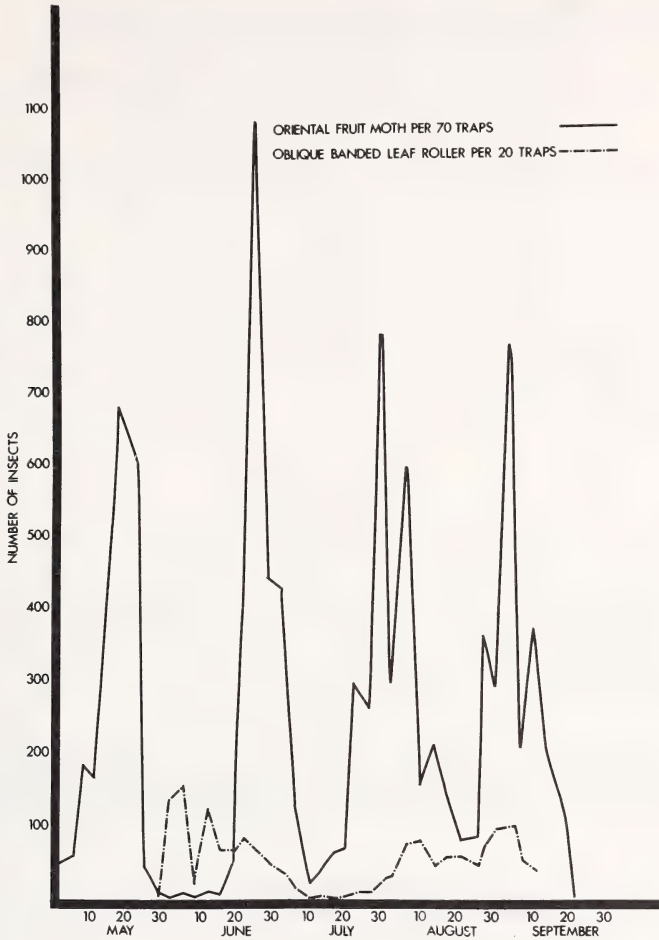


FIG. 2. Captures of obliquebanded leafroller and oriental fruit moth in pheromone traps, Niagara peninsula of Ontario, 1977.

the initial increase in moth catches (egg hatch) followed by an application of phosmet ca. 14 days later.

The data indicate that a special spray, timed to coincide with first hatch of OBLR eggs, was necessary. Because of extended periods of high numbers of adults captured in pheromone traps, one spray application was not adequate. Only one specially timed spray was needed, however, because a regular spray for control of oriental fruit moth usually follows ca. 2 weeks after the first spray for OBLR larvae (Fig. II).

Pesticides should be applied before larvae enter the split pits because larvae were not killed by sprays applied after this time (Table III). The data further show that sprays of phosmet or azinphosmethyl applied 9-12 days after an initial increase in moth captures were effective. Although there are two generations of OBLR, special controls for the second generation appear unnecessary. This may

TABLE III. Control of first-instar obliquebanded leafroller larvae on peach^a

Treatment	Rate (kg A.I./ha)	Application Date	% Normal ^b Peaches Damaged	% Split-Pit ^c Peaches Infested
1977				
Phosmet	2.1	14/6	—	0
	2.1	29/6		
Phosmet	2.1	14/6	—	4
	1.1	29/6		
Phosmet	1.1	14/6	—	12
	1.1	29/6		
Phosmet	1.1	29/6	—	36
Unsprayed				40
1978				
Azinphosmethyl	0.75	28/6	0	0
Phosmet	2.0	7/7		
Unsprayed			5.3	4.0

^a cv. Earlired^b based on examination of 75 peaches/plot 19 July 1978^c based on examination of 25 peaches/plot 12 July 1977
19 July 1978

be, in part, because few of the later peach varieties produce peaches with split pits and larvae are unable to escape insecticide applications for control of oriental fruit moth.

Acknowledgments

We thank F. Kaethler and D. Duhaime for their technical assistance and E. Muir and R. Wright for the use of their orchards.

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(Received 10 March 1981)

**A STUDY OF *BALAUSTIUM PUTMANI*
(ACARINA: ERYTHRAEIDAE)
IN APPLE ORCHARDS IN SOUTHERN ONTARIO**

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Abstract

Proc. ent. Soc. Ont. 112: 13-22 (1981)

This study reports the numerical assessment of field populations of *Panonychus ulmi* Koch and its predator *Balaustium putmani* Smiley, which is bivoltine in southern Ontario. The prevalence of *B. putmani* suggests that its ability to survive in treated orchards might be due as much to the methods by which the pesticides are applied as to the cryptic habits of the predacious mites, and to the survival of alternate hosts, such as the eriophyid *Aculus schlechtendali* (Nal.), as to development of resistance to pesticides.

Introduction

Predacious mites in the genus *Balaustium* Heyden occur widely throughout the holarctic region and are frequently mentioned in acarological literature. Southcott (1961) comprehensively reviewed the family in which this genus is placed. The genus was reported on a wide variety of host plants in North America (Putman 1966, 1970; Smiley 1968). However to date, *Balaustium putmani* Smiley has been reported in southern Ontario only on peach, apple, plum and pear trees (Putman 1970; Cadogan 1976).

From 1960 to 1970, significant numbers of *B. putmani* appeared in apple orchards in which chemicals were used in southern Ontario. This apparent development of resistance to pesticides, plus the inherent capacity of *B. putmani* to feed on phytophagous mites and small insects have renewed interest in this predator for use in integrated pest management.

This study was pursued to assess populations of *B. putmani* in the field and to evaluate their relationship within the acarine complex in apple orchards.

Materials and Methods

From 1 May to 30 Oct. 1974 and from 25 Apr. to 25 Aug. 1975, five apple orchards in southern Ontario were sampled weekly to determine the bionomics of *B. putmani* and associated predacious mites, their prey the European red mite, *Panonychus ulmi* Koch, and other phytophagous mites. Three orchards, Chudleigh, Glengate and McCarthy, were commercial enterprises in Halton County and the others were the Horticulture, and Guelph Research orchards which are affiliated with the University of Guelph.

Five trees were chosen randomly in each orchard. Weekly samples of 20 leaves were taken at random from each tree and examined under a binocular microscope to identify and enumerate the fauna. Because *B. putmani* preferentially occupies the fruit and woody branches of the tree where it oviposits and develops and is only transient on the leaves, the method of 'direct observation' of Weseloh

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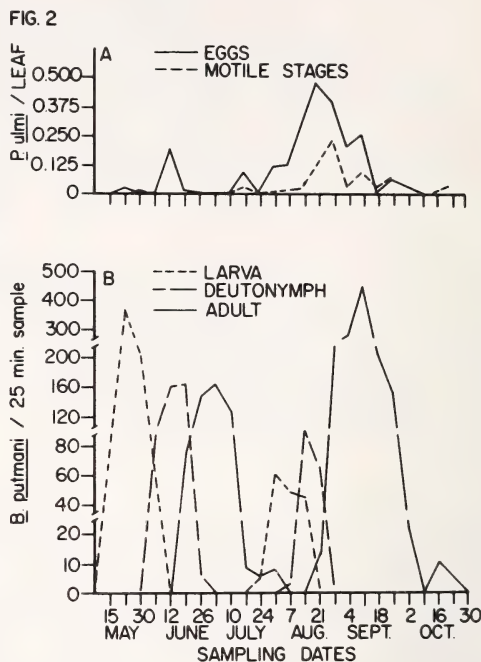
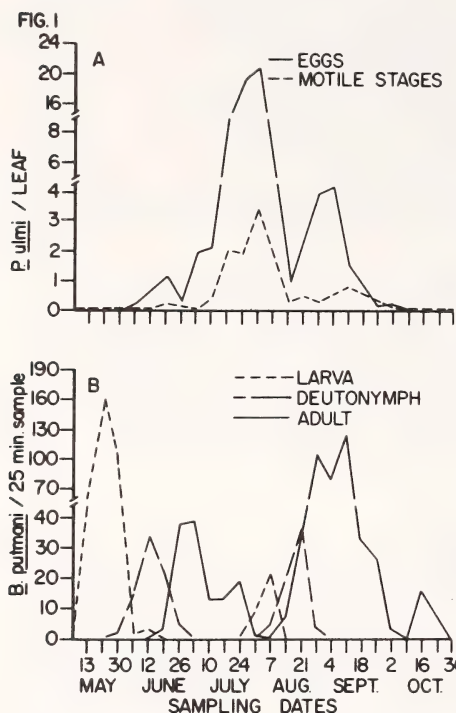


FIG. 1. Population fluctuations of (A) *P. ulmi* and (B) *B. putmani* in the Chudleigh orchard, Halton County, Ontario, during 1974.

FIG. 2. Population fluctuations of (A) *P. ulmi* and (B) *B. putmani* in the Glengate orchard, Halton County, Ontario, during 1974.

(1974) was the most accurate for assessing this predator. Counts of 5-minute duration were taken on the leaves and bark of each tree, and because sunlight seemed to initiate activity of arboreal erythraeids, direct observations were made only during sunny periods.

Observations were made, and leaf samples taken during approximately the same time period each week. The rates, dates and methods of pesticide application for these orchards appear in Table III. Kinkelder® spray machines (operating at low volume, 225 L/ha) were used in orchards in Wellington County, and in the Chudleigh and Glengate orchards in Halton County. A John Beam® 'Speed Spray' air blast machine (calibrated to deliver 3,370 L/ha) was used in the McCarthy orchard.

Results and Discussion

B. putmani overwinters in the egg stage throughout its range. The eclosion of the eggs, which overwinter in deep crevices in the bark and beneath bark scales, is dependent on temperature and moisture (Putman 1970; Cadogan and Laing 1977). The first larva was observed on 13 May 1974 in the Chudleigh orchard (Fig. 1B) and on 15 May 1974 in both the Glengate orchard (Fig. 2B) and the Guelph Research orchard (G.R.O.) (Fig. 4). However, larvae were not observed in the Horticulture orchard until 27 May 1974 (Fig. 3). This late appearance may be an artifact due to the low numbers present in the orchard or

FIG. 3

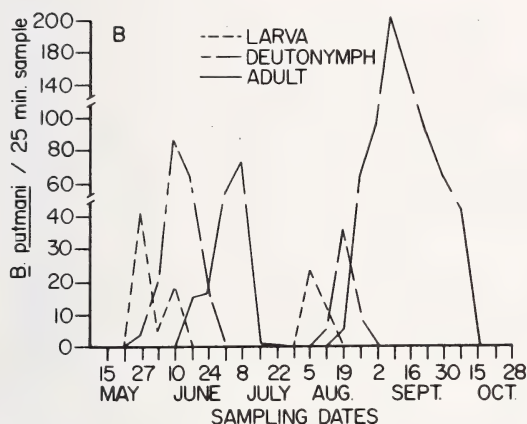
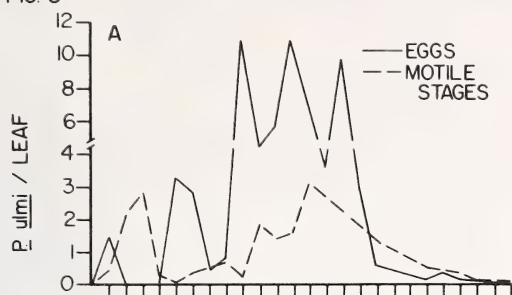


FIG. 3. Population fluctuations of (A) *P. ulmi* and (B) *B. putmani* in the Horticulture orchard, Guelph, Ontario, during 1974.

FIG. 4. Population fluctuations of *B. putmani* in the Guelph Research Orchard, Guelph, Ontario, during 1974. *P. ulmi* were present but in insufficient numbers to appear on the graph.

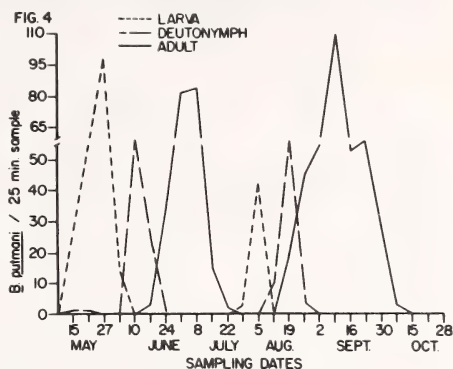
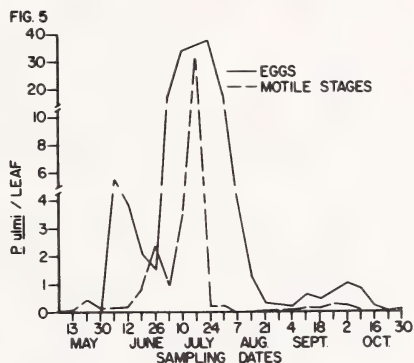


FIG. 5. The *P. ulmi* population in the McCarthy orchard, Halton County, Ontario, during 1974. *B. putmani* was not found in this orchard.



the early treatment of the orchard with Guthion. Newly emerged larvae usually remained beneath bark scale on the trunks and scaffold limbs of the trees and were observed feeding on the apple rust mite, *Aculus schlechtendali* (Nal.), which overwinters beneath the bark. They also fed on the overwintered eggs and the larvae of *P. ulmi*. As larval *B. putmani* matured, they foraged over a larger area and were seen searching for prey on the apple leaves and feeding on pollen grains when the trees were in blossom. The first-generation larvae were observed for periods of 14-30 days (Table I).

The sessile, protonymphal and tritonymphal stages utilized cryptic sites under loose bark to metamorphose. Disturbing these sites would have resulted in high mortality and a possible change in behaviour of subsequent stages. Thus, no numerical data were taken for these stages.

Small numbers of deutonymphs were first observed on 15 May 1974 in the G.R.O. (Fig. 4). This suggests that a few eggs must have hatched prior to 15

TABLE I. Duration of the various motile stages of *B. putmani* in four apple orchards in southern Ontario (1974)

Orchard	No. Days of Each Stage					
	Larvae		Deutonymphs		Adults	
	First Gen.	Second Gen.	First Gen.	Second Gen.	First Gen.	Second Gen.
G.R.O.	18	13	7	14	35	49
Horticulture	14	7	28	14	21	56
Chudleigh	30	7	27	21	41	70
Glengate	23	21	21	21	41	63

May, the date the first larvae were observed. The larvae from the first few eggs to hatch probably were well-hidden and largely inactive due to cool temperatures, and thus were not detected. The deutonymphs foraged throughout the tree, moved very quickly and were elusive. Although they were observed most commonly on the trunk and woody branches, they were also seen on the leaves and fruit, feeding on eriophyids, all stages of *P. ulmi*, aphids, and the eggs of some Tortricidae and Hemiptera. First-generation deutonymphs were recorded in the various orchards for periods of 7-28 days (Table I).

Adults of the first generation were observed in four orchards from 17 June to 31 July 1974 (Figs. 1-4). They fed on the same prey as the deutonymphs. However, adults constantly were exploring cavities and recesses. This, presumably, was to select sites that were suitable for oviposition, resting or avoiding unfavorable periods as the motile stages of *B. putmani* usually remained beneath bark scales during cold, wet, or cloudy periods.

No concerted effort was made to sample eggs laid in bark crevices by the first-generation adults as they are unusually well-hidden and destructive sampling would have exposed them to unusual predation and/or desiccation and resulted in inaccuracies in population estimates. However, a batch of eggs was observed on 4 July 1974 and although no attempt was made to remove it, we estimated that it contained 60 eggs. Eggs of *B. putmani* were also observed inside the calyx cavity of Duchess apples and in necrotic leaves which had been rolled by larval Tortricidae. Eggs apparently are deposited in sites which retain moisture and may reduce loss from predators.

In 1974, the larvae of the second generation were encountered first on 24 July in the Glengate orchard (Fig. 2B). The immature stages of the second generation of *B. putmani* developed faster than those of the first generation due to warmer weather during the second generation and the adults were observed for longer periods (Table I, Figs. 1-4).

Grandjean (1959) observed collections of overwintering eggs of *Balaustium florale* Grandjean which contained several thousand eggs and about 100 decayed female bodies. During our observations many batches of eggs were discovered but the largest number of eggs recovered from one site was 360 with the bodies of three adult erythraeids being identifiable. It was reported by Cadogan and Laing (1977) that females oviposited a number of times in the laboratory and this also likely occurs in the field. Several *B. putmani* of the second generation oviposited their overwintering eggs in the same site. It was also evident that certain sites were used repeatedly over a number of years.

TABLE II. Seasonal relationships between *B. putmani* and the acarine complex in five apple orchards in 1974 (means of 25 weekly samples)

Orchard	Sample Tree and Variety	<i>Balaustium putmani</i> (seasonal mean/min)	Phytoseiid-Stigmaeid Complex (seasonal mean/leaf)	Ratio Stigmaeid to Phytoseiid	<i>Panonychus ulmi</i> (seasonal mean/leaf)		Leaves Infested with Eriophyids (%) (seasonal mean) †
					Eggs	Motile Stages	
Horticulture	1 D	3.3	1.0	20.6:1	0.2	0.1	64.0
	2 S	3.2	2.3	1.2:1	5.0	1.2	53.8
	3 ML	0.9	2.2	32.4:1	6.4	3.4	50.2
	4 M	2.9	0.7	7.3:1	0.4	0.2	59.6
	5 M	0.2	1.9	32.2:1	1.1	0.3	46.6
G.R.O.	1 M	2.0	0.8	2.9:1	0	0	55.4
	2 M	1.1	1.7	38.6:1	0	0	52.2
	3 Du	0.8	0.4	15.8:1	0	0	41.2
	4 Du	1.3	0.7	7.6:1	0	0	40.0
	5 M	2.3	0.4	1.6:1	0	0	47.8
Glengate	1 M	6.6	0.1	1:4	0.1	+* ⁶	63.8
	2 M	7.3	0.7	1.8:1	+* ⁴	+* ²	59.6
	3 S	3.3	2.5	14.5:1	+* ²	0	57.2
	4 M	6.0	0.1	1:4	0.2	0.1	53.6
	5 C	4.2	0.2	2.3:1	+* ²	0	47.4
McCarthy	1 M	0	0	0	6.9	1.1	7.2** ³
	2 M	0	0	0	4.2	0.3	0
	3 ML	0	0	0	8.7	3.2	0
	4 M	0	0	0	6.3	1.6	0
	5 M	0	0	0	7.2	2.1	4.2** ²
Chudleigh	1 M	+	1.3	25.3:1	3.5	0.9	30.6
	2 D	5.1	0.1	4.1:1	2.3	0.5	50.0
	3 D	1.8	0.6	14.7:1	2.1	0.4	49.2
	4 D	1.5	0.1	1.6:1	4.5	0.5	46.6
	5 M	0.2	0.8	67.8:1	3.4	0.6	32.8

Varieties: M = McIntosh; D = Red Delicious; C = Cortland; ML = Melba; Du = Duchess; S = Spy.

* Superscripts denote the total number of samples on which mites and eggs were found.

+ = A trace (less than 0.05 as a seasonal mean per leaf).

† Seasonal means of weekly samples taken throughout the growing season of 1974.

TABLE III. Seasonal spray programs in the apple orchards sampled during 1974 in southern Ontario

Orchard	Spray Material Used	Rate (kg/ha)	Application Date
G.R.O.	FUNGICIDES:		
	Cyprex 65W ⁺	2.2	1/5, 16/5
	Cyprex 80W	1.9	23/5, 29/5, 20/6, 17/7, 30/7
	FUNGICIDES:		
HORTICULTURE	Cyprex 65W	1.1 0.9	24/4, 29/4, 7/5, 13/5, 21/5, 29/5, 11/6, 20/6, 4/7 16/7
	INSECTICIDES:		
	Guthion 50W ⁺	0.6 1.1 0.9	21/5 11/6, 20/6, 4/7 16/7
	Lead arsenate ⁺	1.1 1.7	16/7 31/7, 15/8, 3/9
CHUDLEIGH	FUNGICIDES:		
	Cyprex 65W	1.7 2.8 4.5	29/4, 9/5, 14/5-15/5, 17/5, 6/6-7/6, 16/6 25/6-26/6 16/7-17/7, 25/7, 1/8-2/8, 14/8-15/8
	INSECTICIDES:		
	Guthion 50W	1.1	6/6-7/6, 25/6-26/6, 16/7-17/7, 14/8-15/8, 21/8-22/8
ACARICIDES:	Omite 30W ⁺	1.1	1/8-2/8

TABLE III (continued)

Orchard	Spray Material Used	Rate (kg/ha)	Application Date
McCARTHY ¹	FUNGICIDES:		
	Cyprex 65W	0.6	30/4
		1.1	9/5, 16/5-17/5
	Captan 80W ⁺	1.7	13/5, 29/5, 19/6
		1.5	2/5, 6/5, 27/6
		2.8	30/5, 6/6, 14/6, 17/7-18/7
	INSECTICIDES:		
	Guthion 50W	0.7	27/6
		1.5	6/6, 17/7-18/7
	ACARICIDES:		
	Plictran ¹	0.9	17/7-18/7
	Animert	2.2	30/5
GLENGATE	FUNGICIDES:		
	Cyprex 65W	1.3	6/6, 27/6
		1.8	28/4, 10/5, 22/5
		2.2	16/5
	INSECTICIDES:		
	Guthion 50W	0.9	27/6, 22/7
		1.1	6/6, 7/8

⁺ Common, brand and trade name.

¹ Chemicals applied at high volume.

* Animert also possesses insecticidal properties.

Population dynamics. Evaluation of field populations in southern Ontario has illustrated the bivoltine nature of *B. putmani*. The generations are distinct although the three motile stages of each generation overlap to some extent (Figs. 1-4). In the first generation, a large number of larvae was evident, with the exception of the Horticulture orchard (Fig. 3B), followed by a reduction in numbers of subsequent motile stages. In the second generation the reverse was observed; small numbers of larvae were followed by an increase in numbers of surviving nymphs and adults.

The large larval first generation was a result of the fecundity of the large overwintering population of females from the preceding year. The observed decrease in post-larval numbers might be attributed to larval mortality or high mortality of the sessile stages. The apparent anomaly in the second generation might be due to a number of factors. However, it is most likely that weekly sampling failed to detect a large proportion of the larvae which changed from one stage to another much more quickly than during the first generation. Sampling bi-weekly might have given more realistic numbers of the larval and deutonymphal population in the second generation.

B. putmani was observed in commercial orchards in Halton County where low-volume sprays were used, but was absent in those where high-volume sprays were used. This may be because:

- (i) more egg masses and sessile stages would likely be killed by the high-volume sprays which penetrate and inundate crevices;
- (ii) sprays tend to severely reduce eriophyids which are important in maintaining a predacious mite complex. Table II indicates that where there is positive correlation between the presence of eriophyids and a predator complex;
- (iii) *B. putmani* may be resistant to the chemicals used for pest control in some commercial orchards.

Relationships within the mite complex. All of the motile stages of *B. putmani* fed heavily on eriophyids. This is contrary to Putman (1970), who suggested that the small size of the eriophyids would make them unlikely prey for *B. putmani*. It was observed in this study that a predator complex also existed in orchards in which large numbers of eriophyids were present and that all stages of the European red mite were consumed by *B. putmani*. Although most stages of *B. putmani* also fed on all stages of the twospotted spider mite, *Tetranychus urticae* Koch, the larval stage of the predator had difficulty negotiating the webbing of this species.

Table II indicates the co-existence of *B. putmani* with Phytoseiidae and Stigmaeidae. Both of these families contain efficient predators of *P. ulmi* and *T. urticae*. Thus, to observe numbers of all three groups of predators together suggests that competition must have been sufficiently weak to allow their co-existence. Some degree of competition must exist among the predators of the acarine complex in orchards, particularly at low prey densities. However, this complex appears to be effective in combination, which agrees with the observation that competition does not necessarily result in several species of predators or parasites being less effective than one.

A relationship may exist between the saprophytic oribatids and *B. putmani* because the eggs of *B. putmani* are usually laid in areas that contain oribatids, yet we did not observe oribatids feeding on the eggs or *B. putmani* preying on the

oribatids. Further studies are required to examine the relationship between *B. putmani* and this saprophyte.

The apparent stability of *P. ulmi* at low levels in Guelph Research and Glengate orchards (Fig. 2), might be due to a stabilized predator complex, the result of conservative spray applications (Table III). Although *P. ulmi* was found in the G.R.O., insufficient numbers occurred for them to appear in Fig. 4. Peaks in the population density of *P. ulmi* were observed in the Chudleigh and Horticulture orchards (Figs. 1A, 3A). Large numbers of *P. ulmi* in the Chudleigh orchard required a spray to reduce them to acceptable levels. It is likely that in the Chudleigh and Horticulture orchards, the predator complex is still in a state of change (*B. putmani* having been observed first in 1972 in both orchards) which would contribute to the cyclical nature of the phytophagous mite population.

The McCarthy orchard, which contained no predators (Table II), also required an acaricide to control the high densities of *P. ulmi* (Table III, Fig. 5). *B. putmani* was observed in all but this orchard during this study. However, *B. putmani* was not an exclusive predator in any of these orchards. Thus, it was not possible to attribute the low numbers of phytophagous mites, which were observed in two of the orchards, exclusively to any one species, but rather to the complex of predators as a whole.

The apple rust mite, which is utilized as a primary source of food by *B. putmani*, was absent in the McCarthy orchard but present in all of the other orchards with a complex of predatory mites. From these observations, it would be desirable to encourage certain levels of eriophyids as proposed by Herbert and Sanford (1969) and Holdsworth (1974) to provide food and alternative prey for the complex of predacious mites found in apple orchards. When the schedules of pesticide applications, used to control various orchard pests, are designed to preserve natural enemies and their alternate hosts, *B. putmani* should become a valuable member of the predacious mite complex in apple orchards.

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TABLES OF DAILY DEVELOPMENT FOR THE LIFE STAGES OF THE ALFALFA WEEVIL, *HYPERA POSTICA* (COLEOPTERA: CURCULIONIDAE)¹

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Abstract

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User tables relating to a polynomial algorithm for predicting seasonal development of the alfalfa weevil, *Hypera postica* (Gyll.) in southern Ontario are described.

Introduction

Harcourt and Yee (1982) have developed a polynomial algorithm for predicting duration of the life stages of the alfalfa weevil, *Hypera postica* (Gyll.). The algorithm interpolates a daily temperature curve from maximum and minimum temperatures, integrates this curve at 3-h intervals, and accumulates proportionate development until the cumulative sum is greater than, or equal to, 1.0. The most intricate and tedious step in the method is that of calculating proportionate development over an interval. To expedite these calculations, we have generated tables listing proportions of daily development for 7 life stages of the weevil at maximum and minimum daily temperatures. Abbreviated tables for 2 of the stages are given in Table I. Complete sets can be obtained from the authors upon request.

Tables of Development

Derivation. From equation 3 of Harcourt & Yee (1982) the development over 1 day is

$$\int_0^1 \text{rate} \quad (\text{stage}) \quad (\text{temperature } (t)) \quad dt.$$

The integral is numerically approximated using Simpson's Rule (Peterson 1960) with 8 intervals.

Since each life stage has its own threshold temperature, the polynomial curve was refined by connecting the developmental rate at the threshold to the origin. The daily temperature curve was approximated by a skewed sine curve with maximum at 1500 h and minimum at 0600 h.

Use of tables. The developmental values are tabulated in increments of 0.0001; thus, a value of 56 represents 0.0056 developmental units (DU). To determine numbers of units acquired during a 24-h period, the appropriate table is used for each life stage. For example, for instar 2 and temperature readings of max. 25°C and min. 15°C, Table I indicates a value of 0.2664. DU values are accrued on a daily basis until cumulative totals equal or exceed unity. DU values for fractional temperatures are interpolated from surrounding values in the tables.

¹Contribution No. 662 from the Ottawa Research Station.

TABLE I. Proportions of daily development for 2 life stages of the alfalfa weevil for a selected range of temperatures

INSTAR 2																								MINIMUM											
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20															
0	0																																		
1	23	44																																	
8	47	67	87																																
3	70	90	110	131																															
4	94	114	134	154	174																														
5	117	137	157	177	197	218																													
6	141	161	181	201	221	241	261																												
7	164	184	204	224	244	264	284	305																											
8	209	229	249	269	289	309	329	349	474																										
9	252	272	292	313	333	374	408	442	564																										
10	288	309	350	384	407	430	464	489	573	616	662																								
11	361	385	408	431	455	489	515	541	629	673	720	771	835	891																					
12	412	435	459	483	518	544	570	620	689	734	783	850	904	962	1024																				
13	466	490	515	550	576	603	630	683	754	801	850	904	962	1024	1171																				
14	526	550	586	613	640	668	696	772	824	872	924	979	1039	1102	1171	1333																			
15	590	626	653	681	709	738	789	847	901	950	1003	1060	1121	1187	1258	1333	1512																		
16	670	698	726	755	784	814	868	928	983	1035	1089	1148	1211	1279	1351	1429	1512	1708	1923																
17	748	777	806	835	865	896	954	1016	1073	1126	1182	1243	1307	1377	1451	1531	1617	1708	1923	2159															
18	832	862	892	922	954	1008	1046	1111	1169	1224	1282	1344	1411	1483	1560	1642	1729	1823	1923	2159	2415														
19	923	954	985	1017	1049	1106	1146	1213	1273	1330	1390	1454	1523	1597	1676	1760	1850	1946	2049	2159	2415														
20	1022	1053	1086	1118	1152	1212	1274	1323	1385	1444	1506	1572	1643	1719	1800	1887	1979	2078	2183	2296	2415														
21	1128	1161	1194	1228	1285	1326	1391	1442	1506	1566	1630	1699	1772	1850	1933	2023	2118	2219	2327	2442	2564														
22	1242	1276	1311	1346	1407	1449	1517	1569	1635	1697	1764	1834	1910	1990	2076	2168	2265	2369	2480	2598	2723														
23	1365	1400	1436	1473	1537	1581	1651	1706	1774	1838	1906	1979	2057	2140	2229	2323	2423	2530	2643	2764	2892														
24	1497	1534	1571	1632	1676	1722	1795	1852	1922	1988	2059	2135	2215	2300	2391	2488	2591	2700	2817	2940	3071														
25	1639	1677	1715	1779	1826	1873	1950	2008	2080	2149	2222	2300	2383	2471	2564	2664	2769	2882	3001	3128	3262														
26	1790	1830	1870	1937	1985	2056	2114	2175	2249	2320	2396	2476	2561	2652	2748	2851	2959	3075	3197	3327	3464														

MAXIMUM

MAXIMUM

TABLE I (continued)

		INSTAR 3																				
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	0																					
1	21	38																				
2	41	59	76																			
3	62	79	97	114																		
4	82	100	117	135	152																	
5	103	120	138	155	173	190																
6	123	141	158	176	193	211	228															
7	144	161	179	196	214	231	249	266														
8	178	195	213	230	248	265	283	300	387													
9	207	225	242	260	277	309	333	358	411	435												
10	235	253	285	309	327	346	372	391	447	474	510											
11	291	309	327	347	366	393	413	435	493	524	563	611										
12	333	353	373	393	421	443	465	502	550	583	626	677	735									
13	385	406	428	456	479	502	526	565	616	652	698	752	813	882								
14	446	468	498	521	545	570	596	651	690	730	779	835	899	970	1048							
15	514	545	569	593	619	646	687	731	774	816	867	926	993	1067	1147	1233						
16	597	622	647	674	701	730	773	819	864	910	963	1025	1094	1170	1252	1340	1434					
17	679	706	733	761	790	820	865	914	962	1010	1066	1130	1202	1280	1364	1454	1550	1650				
18	769	797	826	855	886	931	964	1016	1066	1117	1175	1242	1315	1395	1481	1573	1671	1772	1878			
19	864	894	924	955	987	1033	1069	1123	1176	1229	1290	1358	1434	1516	1604	1698	1796	1900	2007	2118		
20	965	996	1027	1060	1093	1141	1193	1235	1291	1346	1409	1480	1557	1641	1731	1826	1926	2031	2140	2252	2367	
21	1071	1103	1136	1169	1217	1254	1307	1352	1410	1467	1532	1605	1684	1770	1862	1958	2060	2166	2276	2389	2505	
22	1181	1214	1248	1282	1332	1370	1426	1473	1533	1592	1659	1734	1815	1902	1995	2093	2196	2304	2414	2529	2645	
23	1294	1328	1363	1399	1450	1490	1548	1597	1659	1720	1789	1866	1948	2037	2132	2231	2335	2443	2555	2670	2788	
24	1410	1446	1482	1532	1571	1613	1672	1723	1787	1851	1922	1999	2084	2174	2270	2370	2475	2585	2697	2813	2931	
25	1529	1565	1602	1653	1694	1738	1799	1852	1918	1983	2055	2135	2220	2312	2409	2511	2617	2727	2840	2956	3075	
26	1649	1686	1724	1777	1819	1877	1927	1982	2049	2116	2190	2271	2358	2451	2549	2651	2758	2869	2983	3100	3219	

MAXIMUM

MAXIMUM

Generally, completion of a stage will not coincide with the end of a day. Hence, there will be an excess of units accumulated on the day of transition to the next stage. This surplus cannot be directly assigned to the next life stage because developmental rates vary between the stages. The surplus is carried over as shown in the following example where 0.6354 DU had already been accumulated:

Day	Stage	Max.	Min.	DU generated	Cumulative DU (at end of day)
n					0.6354
n+1	Instar 2	25	15	0.2664	0.9018
n+2	Instar 2	20	10	0.1506	1.0524
n+2	Instar 3	20	10	0.1409 (0.348)	0.0490
n+3	Instar 3	22	12	0.1815	0.2305

On day $n + 1$, with a maximum and minimum of 25 and 15, 0.2664 DU were generated to provide a running total of 0.9018 units. On day $n + 2$, a further 0.1506 DU were generated. Thus 0.0524 DU were unnecessary for instar 2 development, and instar 3 accumulated units for a portion of that day. This represents 34.8% of the 0.1506 DU accrued on day $n + 2$. This proportion is carried forward to instar 3 and represents $0.1409 (0.348) = 0.0490$ DU. These are added to the tally for day $n + 3$.

Practical considerations dictate a moderate degree of "rounding" to minimize the allocation of surplus units. The range of values one chooses to round is entirely subjective; however, for the alfalfa weevil, we suggest rounding at $\pm 5\%$ of total stage development.

Other considerations. Certain events do not correspond to a definitive life stage, e.g. peak hatch or cocooning. In these cases, the events are deemed to occur when development is partially complete and DU requirements will be less than 1.0. Proportional stage development is accommodated as follows:

Present stage/event	Next stage/event	Table to use	Cumulative DU
Hatch	Instar 1	Instar 1	0.50
Instar 4	Cocooning	Instar 4	0.50
Cocooning	Prepupa	Instar 4	0.50

The point at which the accumulation of developmental units begins is governed by pest management considerations. In southern Ontario, egg-laying occurs during a protracted period in early spring. However, peak hatch reliably follows the accumulation of 155 °D_s from April 1 (Harcourt 1981). This is equivalent to a total of 1.64 egg DU.

Validation of tables. The tabular values may be expected to differ from the internal computer values because of rounding, truncation, and approximation error. A further discrepancy may arise from the practice of carrying forward excess developmental units from one stage to the next. These errors can accumulate and result in variation between the dates predicted by tabular and computer calculation.

The predictive value of the two methods was compared using data for two areas of southern Ontario in 1981. Table II shows that both methods gave a good fit to the observed data and that there was little to choose between their predic-

TABLE II. Comparison of two methods for predicting peak occurrence of the alfalfa weevil in two areas of Ontario in 1981

Stage or event	Bay of Quinte			Guelph		
	Observed	Computer	Tabular	Observed	Computer	Tabular
Hatch	May 28	May 28	May 28	June 3	June 3	June 3
Instar 1	May 31	May 30	May 30	June 6	June 5	June 5
Instar 2	June 5	June 5	June 5	June 11	June 10	June 10
Instar 3	June 10	June 10	June 10	June 15	June 15	June 15
Instar 4	June 15	June 15	June 15	June 20	June 19	June 19
Cocooning	June 18	June 18	June 18	June 24	June 24	June 23
Prepupa	June 22	June 22	June 22	June 28	June 27	June 27
Pupa	June 25	June 27	June 26	July 2	July 1	July 1
Adult	July 3	July 4	July 4	July 8	July 8	July 8

tions of weevil development at either location. It is concluded that for practical purposes, the tabular method will result in predictions as accurate as those generated by computer.

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**DAMAGE TO SWEET PEPPER IN ONTARIO BY THREE STRAINS OF
EUROPEAN CORN BORER,
OSTRINIA NUBILALIS
(LEPIDOPTERA: PYRALIDAE)**

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Abstract

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The levels of infestation produced by three strains of the European corn borer, *Ostrinia nubilalis* (Hbn.), on peppers at London, Ontario were significantly different. The strain from London, Ontario, which had one generation per year, infested more peppers than did strains from Wallacetown, Ontario or New York which had two generations per year. There were also significant differences in infestation among pepper varieties.

Introduction

The European corn borer, *Ostrinia nubilalis* (Hbn.), can cause severe damage to peppers grown in southwestern Ontario (Foott and Timmins 1969). In Essex and Kent counties, where two-thirds of the pepper crop is grown, damage is caused by the early emerging or 2-generation strain (Wressell 1970). However, substantial acreages of peppers also are grown in Norfolk and Middlesex counties where the late-emerging or 1-generation strain occurs (McLeod 1976). Damage in these areas is usually less and can be attributed to the paucity of corn borers when the pepper fruit are maturing, or to the inability of the 1-generation strain to infest peppers. This paper describes two years of data testing the latter hypothesis.

Materials and Methods

Three corn borer strains were maintained in the laboratory on artificial diet as described previously (McLeod 1976). The 1-generation strain was from London and the 2-generation strain from Wallacetown, Ontario. The New York strain was from Geneva and had two generations per year but differed from the others in its pheromone system (Liebherr and Roelofs 1975).

Three varieties of pepper, Earliest Red Sweet, Early Niagara Giant and Early Sweet Banana, were planted on the Research Centre's field station north of London on 9 June 1980 and 8 June 1981. Plants were 46 cm apart in the rows with 91 cm between rows. A randomized complete block design was used. Every other plant in the row was numbered from 1 to 40 then the row was divided into 10 replicate blocks of 4 numbered plants each. Plants infested with one of the corn borer strains or used as controls (not infested) were located randomly within each block.

Egg masses of 25-40 eggs in the black-head stage, and therefore ca. 4 days old at 22°C each, were pinned to a leaf in the centre of the plant. Plants were infested once a week for four consecutive weeks beginning 6 August 1980 and 18 August 1981. Mature fruit were removed and examined for damage by corn borer

¹Supplied by Dr. W. Roelofs, New York Experiment Station, Geneva, New York.

TABLE I. Average percentage of three varieties of pepper infested per week by three strains of European corn borer

Variety and Strain	Infested Fruit Mean $\pm$ S.E.	
Pepper Variety		
Earliest Red Sweet	37.9 $\pm$ 5.4	A ^a
Early Sweet Banana	9.5 $\pm$ 2.4	B
Early Niagara Giant	7.2 $\pm$ 2.4	B
Corn Borer Strain		
London	33.6 $\pm$ 5.2	A
Wallacetown	23.1 $\pm$ 3.6	B
New York	14.6 $\pm$ 2.2	B
Control	1.3 $\pm$ 1.0	C

^a Means within each group followed by the same letter are not significantly different from each other at the 5% level of significance.

each week beginning 20 August 1980 and 31 August 1981. Seven weeks later on the last sampling date, all large fruit were removed and examined for borer damage.

The data, expressed as percentage of infested fruit each week, were subjected to analysis of variance and the average of the weekly infestation rates tested with Duncan's multiple range test.

Results and Discussion

Analysis of variance gave highly significant F-values for both pepper varieties (30.73; $df=2, 138$) and corn borer strains (14.73; $df=3, 138$). There was no significant difference ($P > 0.05$) between years in the total percentage of infested fruit (1980 20.7%, 1981 15.6%). The interactions were not significant. The variety Earliest Red Sweet was the most susceptible to infestation, with no susceptibility difference between Early Niagara Giant and Early Sweet Banana (Table I). In 1980, a few cold nights shortly after transplantation apparently affected fruit set and only 365 fruit were obtained over the season from all varieties. Fruit set was adequate in 1981 and over 1100 fruit were examined for corn borer damage.

The wide range in susceptibility of pepper varieties to corn borer infestation also was shown by Foott and Timmins (1969). They suggested that resistance was primarily a non-preference for oviposition as corn borers placed directly on fruits of different varieties survived equally well. However, in this study ovipositional preference was not a factor because the eggs were placed on the plants. The close-fitting calyx and smooth, rounded stem-end of the Early Sweet Banana variety may have hindered entry into the fruit because most infested fruit were entered in this area. However, fruit of the variety, Early Niagara Giant, superficially resemble the fruit of the Earliest Red Sweet variety in placement and tightness of fit of the calyx (Fig. 1) but had significantly less infestation (Table I).

The highest infestation was obtained with the London strain of corn borer (Table I). The infestations produced by the Wallacetown and New York strains were not different from each other but were significantly higher than the control.



FIG. 1. Top view of pepper fruit showing attachment of calyx to fruit. Early Niagara Giant (left), Earliest Red Sweet (right), Early Sweet Banana (top). Note space between calyx and fruit of bottom two specimens.

The interaction between corn borers and peppers can be expressed in terms of resistance or susceptibility of the pepper variety or as survival rates of corn borer on different pepper varieties. Survival rate also was shown to differ in three biotypes of the corn borer attacking field corn in North America (Sparks *et al.* 1966).

This study demonstrates that if resistance to corn borer becomes a part of a pepper breeding program, the source of corn borer used to test this resistance will influence the infestation. If natural populations are used to assess resistance, different locations with different strains could give rise to different rates of infestations. These results also suggest that the lower rates of infestation in the one-generation area are the result of the scarcity of corn borers at a time when peppers are at a susceptible stage of growth.

Acknowledgments

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**DISTRIBUTION OF *MICROCTONUS COLESI*
(HYMENOPTERA: BRACONIDAE), A NEW PARASITE OF THE
ALFALFA WEEVIL IN ONTARIO¹**

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Abstract

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Microctonus colesi Drea, a univoltine parthenogenic parasite of the alfalfa weevil, *Hypera postica* (Gyllenhal), has become established throughout most of southern Ontario. A detailed survey in 1981 showed that it was present in 39 of 41 counties, and that rates of attack at 80 sample sites ranged from 1 to 52%, averaging 13. Dispersal in Ontario has been the result of natural spread and recolonization from the United States.

Introduction

Since the mid 1970's, populations of the alfalfa weevil, *Hypera postica* (Gyllenhal), in southern Ontario have been regimented by natural epizootics of a disease caused by 2 fungi that attack the larval and cocooned stages (Harcourt *et al.* 1977, 1981; Harcourt 1981a). Although mortality rates are density-dependent, the disease is not entirely compensating in its action and this imposes population oscillations that are not coincidental in time and place. As a result, scattered outbreaks of the weevil still occur, and damage persists. During the past 4 years, the weevil has been parasitized in increasing numbers by 2 species of introduced braconid wasps, *Microctonus aethiopoides* Loan and *M. colesi* Drea. The former, which attacks the adult stage, is compatible with the disease and has added a measure of stability to weevil populations. The latter, which attacks the larval stage, is less compatible with the disease since it competes for the same stage of the host. Whereas *M. aethiopoides* is established throughout southern Ontario (Harcourt *et al.* 1980), the distribution of *M. colesi* is not known.

M. colesi is univoltine and unisexual. In southern Ontario, the adults emerge from their cocoons in late May or early June and begin to attack the larger weevil larvae. The eggs are laid inside the body cavity of the host. These usually hatch before the host pupates and the larvae carry through to the adult stage of the host where they overwinter in the first instar. In early spring, the larvae mature, emerge from their hosts, and spin cocoons in the ground litter. Both sexes of the adult weevil are rendered sterile in the year of attack. The general biology of *M. colesi* has been outlined by Brunson and Coles (1968) and Dysart and Day (1976).

Thought to be of European origin, *M. colesi* was first discovered in the eastern United States in 1962 (Coles and Puttler 1963), and by 1976, was reported from 13 contiguous states (Dysart and Day 1976). In Canada, 37 adults obtained from the USDA Beneficial Insects Laboratory at Moorestown, N.J., were released at South Bay, Prince Edward county, Ontario in 1970 (Williamson

¹Contribution from the Ottawa Research Station (No. 660) and the University of Guelph. This research was supported in part by the Ontario Ministry of Agriculture and Food.

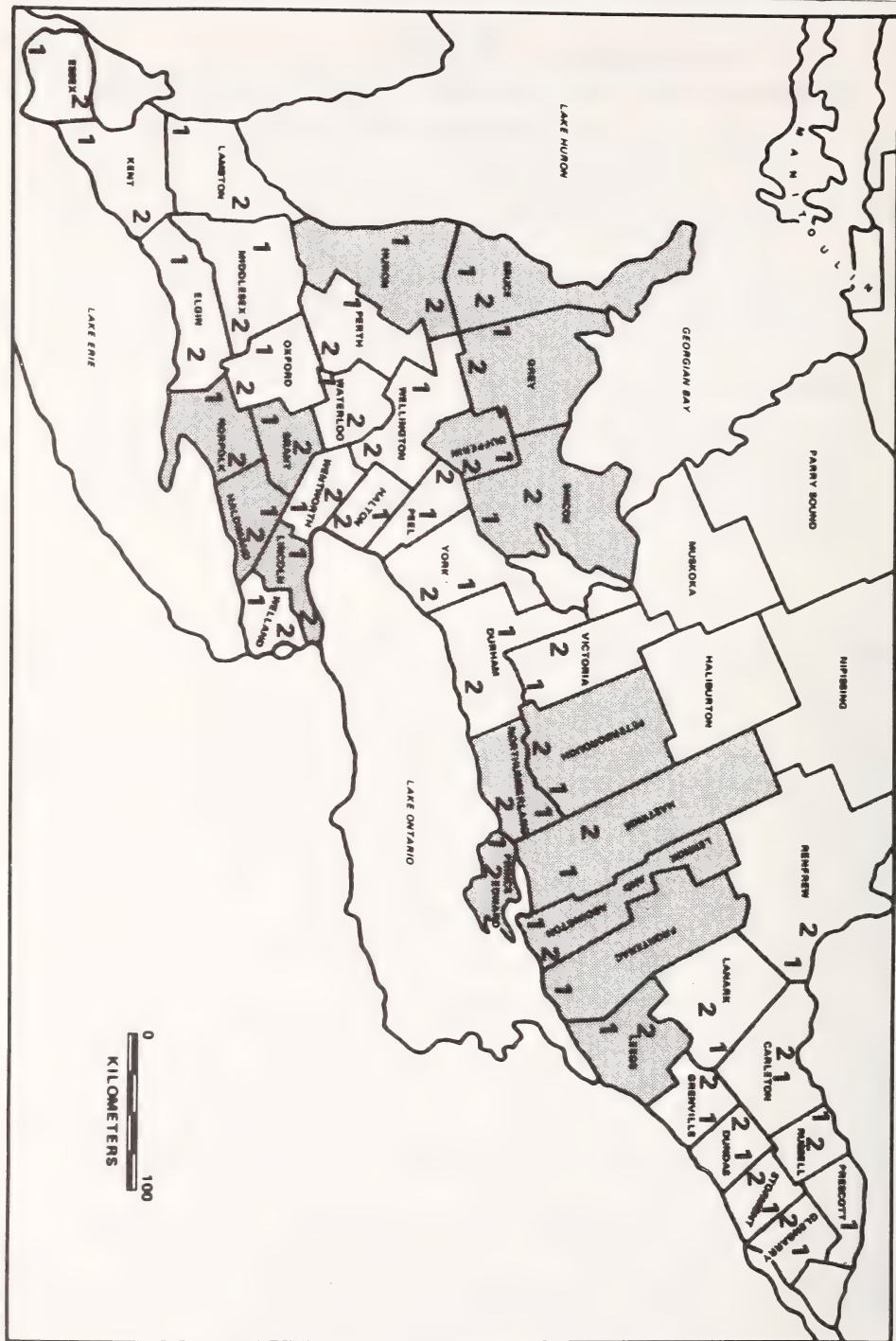


FIG. 1. Sampling sites for *M. colasi* in southern Ontario, 1981. Counties where parasites were found are shaded; those where rates of attack averaged 15%, or more, are shaded in darker grey.

TABLE I. Parasitism of the alfalfa weevil in Ontario by *M. colesi*, 1981

County	Site	% Parasitism	County	Site	% Parasitism
Brant	1	32.0	Lincoln	1	40.0
	2	2.0		2	40.0
Bruce	1	34.0	Middlesex	1	6.0
	2	28.0		2	22.0
Carleton	1	2.0	Norfolk	1	14.0
	2	6.7		2	18.0
Dufferin	1	40.0	Northumberland	1	25.0
	2	7.0		2	5.0
Dundas	1	2.0	Oxford	1	6.0
	2	0.0		2	4.0
Durham	1	8.0	Peel	1	2.0
	2	4.0		2	10.0
Elgin	1	6.0	Perth	1	2.0
	2	4.0		2	10.0
Essex	1	4.4	Peterborough	1	9.7
	2	2.0		2	24.0
Frontenac	1	50.0	Prescott	1	7.9
	*	—		*	—
Grey	1	42.0	Prince Edward	1	22.0
	2	16.0		2	18.0
Glengarry	1	6.0	Renfrew	1	23.0
	2	12.0		2	0.0
Grenville	1	18.0	Russell	1	2.0
	2	4.0		2	0.0
Haldimand	1	52.0	Simcoe	1	40.8
	2	42.0		2	6.5
Halton	1	8.0	Stormont	1	4.0
	2	4.0		2	2.0
Hastings	1	28.6	Victoria	1	2.0
	2	16.0		2	9.8
Huron	1	20.0	Waterloo	1	2.0
	2	20.0		2	16.0
Kent	1	0.0	Welland	1	8.0
	2	0.0		2	5.9
Lambton	1	0.0	Wellington	1	10.0
	2	0.0		2	8.0
Lanark	1	12.5	Wentworth	1	8.0
	2	0.0		2	2.0
Leeds	1	24.0	York	1	2.0
	2	25.0		2	0.0
Lennox & Addington	1	11.8			
	2	26.0			

*Sample destroyed by disease

1971). By 1978 the parasite had spread throughout the county and was found in the neighbouring counties of Hastings and Northumberland.

In the Bay of Quinte area, where two of the authors (D.G.H. and J.C.G.) have monitored weevil populations for the past decade, the impact of *M. colesi* was first felt in early 1979 when significant numbers of overwintering adults were found to contain diapausing parasite larvae. The incidence of parasitism was even

greater the following year, and parasitized hosts were also collected from study plots at Guelph and Ottawa. This prompted us to determine the extent of its present distribution in Ontario.

Materials and Methods

During the spring of 1981, final-instar larvae of the weevil were collected from alfalfa fields in each county of southern Ontario. To ensure that peak populations of the host stage were present, samples from all areas were timed between 280 and 330 °D > 9°C (Harcourt 1981b). Sampling began in south-western Ontario on 10 June and was completed progressively later across the province. The larvae were collected with a standard 38-cm sweepnet and a variable number of sweeps, depending on larval density, were made in each of 2 fields in each of 41 counties (Fig. 1). To allow for losses from handling and/or disease mortality, at least 100 larvae were collected per site.

The larvae were brought to the laboratory and reared to maturity on alfalfa foliage. Most pupated within 2-3 days. Following adult metamorphosis, the weevils were fed for a few days and then stored fresh-frozen in sealed vials until dissected. A minimum of 50 adults was dissected per site, 100 per county.

Results and Discussion

More than 4000 weevils were dissected. Table I shows that the parasite was present in 39 of the 41 counties and in all but 9 of 80 sites. Rates of attack ranged from 1 to 52%, averaging 13.

The widespread distribution of *M. colesi* is surprising in view of the fact that it was not known from Ontario prior to 1978. However, its passive dispersal within the adult host would greatly enhance its rate of spread, particularly during weevil outbreaks. Its apparent success further suggests that a mechanism for co-existence with the disease has evolved. A recent study by Loan (1981) indicates that peak attack by *M. colesi* occurs after epizootics of the disease have subsided and that the wasp is able to discern areas within the field where incidence of disease is low.

Reasons for the uninfested pocket in southwestern Ontario and highly infested area bordering Lake Huron and Georgian Bay are not clear. However, the data suggest that *M. colesi* entered southern Ontario through the Niagara frontier adjacent to western New York where it has been known for several years (Gyrisko 1977). High populations in the Bay of Quinte area are attributed to the 1970 release in Prince Edward county.

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DIEL PERIODICITY OF OVIPOSITION BY *CULEX PIFIENS* AND *CULEX RESTUANS* IN SOUTHERN ONTARIO

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Adult mosquito populations have usually been monitored with CDC or New Jersey mosquito traps (Rowley *et al.* 1979; Brust and Ellis 1976). These traps require an energy source, are expensive, often unreliable and non-selective. As a result of these problems the use of oviposition pools was examined as an alternative to monitor populations of *Culex* spp. mosquitoes. By determining the number of egg rafts laid by these species, a relative measure of the population size was available (Madder *et al.* 1980; Maw & Bracken 1971).

DeMeillon *et al.* (1967) found that *Culex pipiens fatigans* Wiedemann in Burma showed a diel periodicity of oviposition with peak activity at dusk and dawn. Oda and Kuhlow (1979) found a similar periodicity with *Culex pipiens pipiens* L. in Germany. This study was designed to determine the diel periodicity in *C. pipiens pipiens* L. and *C. restuans* Theobald in southern Ontario. This would determine when the species had peaks in oviposition activity and when oviposition ceased. The latter factor is significant when pools are used to monitor populations of *Culex* spp. because egg rafts laid should be counted between ovipositional periods.

The adult periodicity of oviposition was studied by collecting and counting the egg rafts laid by *Culex* spp. each hour in 9 artificial pools (Madder *et al.* 1980). Egg rafts collected each hour during the first trial on 14 July 1979 were separated and identified. The ovipositional patterns for *C. pipiens pipiens* and *C. restuans* were not different (Fig. 1A), therefore the egg rafts laid during the 6 trials between 14 July and 8 August were not identified on an hourly basis. No egg rafts were oviposited between 10:00 and 20:00 h during the first trial, therefore the pools were not monitored during these hours on successive nights.

The mean diel periodicity of oviposition by *Culex* spp. in the Guelph area is shown in Fig. 1B. Maximum oviposition occurred within one to three hours of dusk (64%) with a second peak at dawn (15%). These observations are similar to those of DeMeillon *et al.* (1967) and Oda and Kuhlow (1979). Ovipositional activity was complete by 10:00 h, therefore oviposition pools should be assessed after this time to ensure valid estimates of activity.

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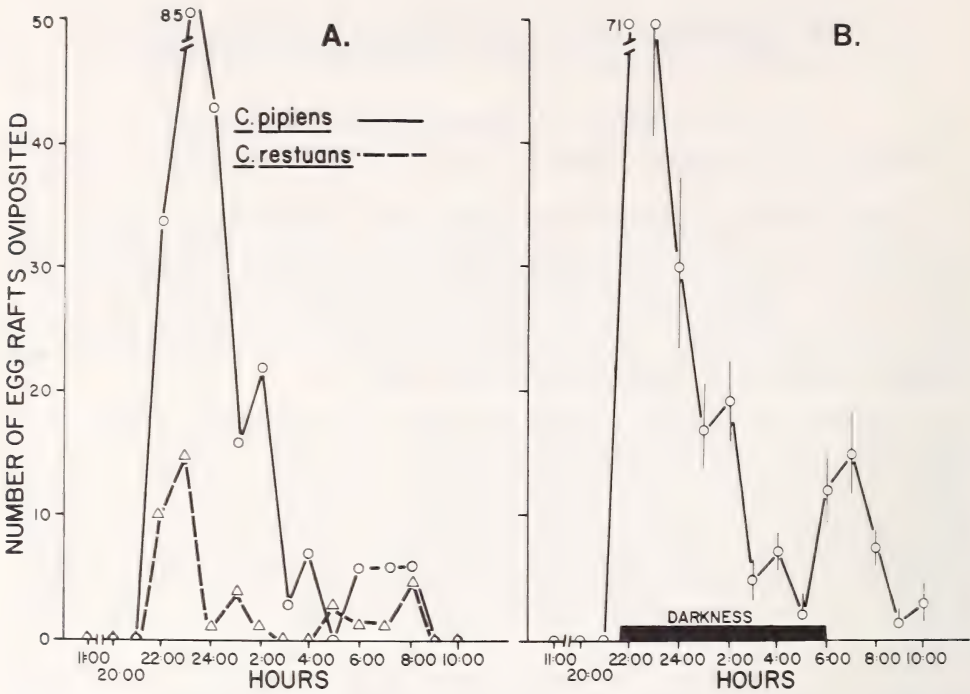


FIG 1. Diel periodicity of oviposition by *Culex pipiens* and *C. restuans* at Guelph. A, 14 July 1978; B, mean oviposition of six trials from 14 July to 8 August.

"DAUER" STAGE NEMATODES PHORETIC UPON SEVERAL ARTHROPOD SPECIES

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We observed numbers of third-stage "dauer" nematodes phoretic upon several arthropods in small quadrats of sliced onions, which were used as an attractant for the onion maggot, *Hylemya antiqua* (Meigen) (Diptera: Anthomyiidae).

Wooden quadrats (1 m²) with 15-cm sides and a screened (600- μ m mesh) bottom were sunk in the soil of onion fields to a depth of about 12 cm. The quadrats were filled to a depth of about 7 cm with brick sand and covered with onions which were sliced in half and planted roots down. About 10,000 eggs of *H. antiqua* were spread over the onions and washed into the sand with sprinkled water. A piece of snow fence which was 1-metre square and placed over the quadrat, acted as a sunscreen. Soon afterwards a large number of parasites, predatory arthropods and saprophages invaded the decomposing onions. The quadrats were monitored at various times by taking sweep samples and soil cores which were extracted by modified Tullgren funnels (Tomlin 1978).

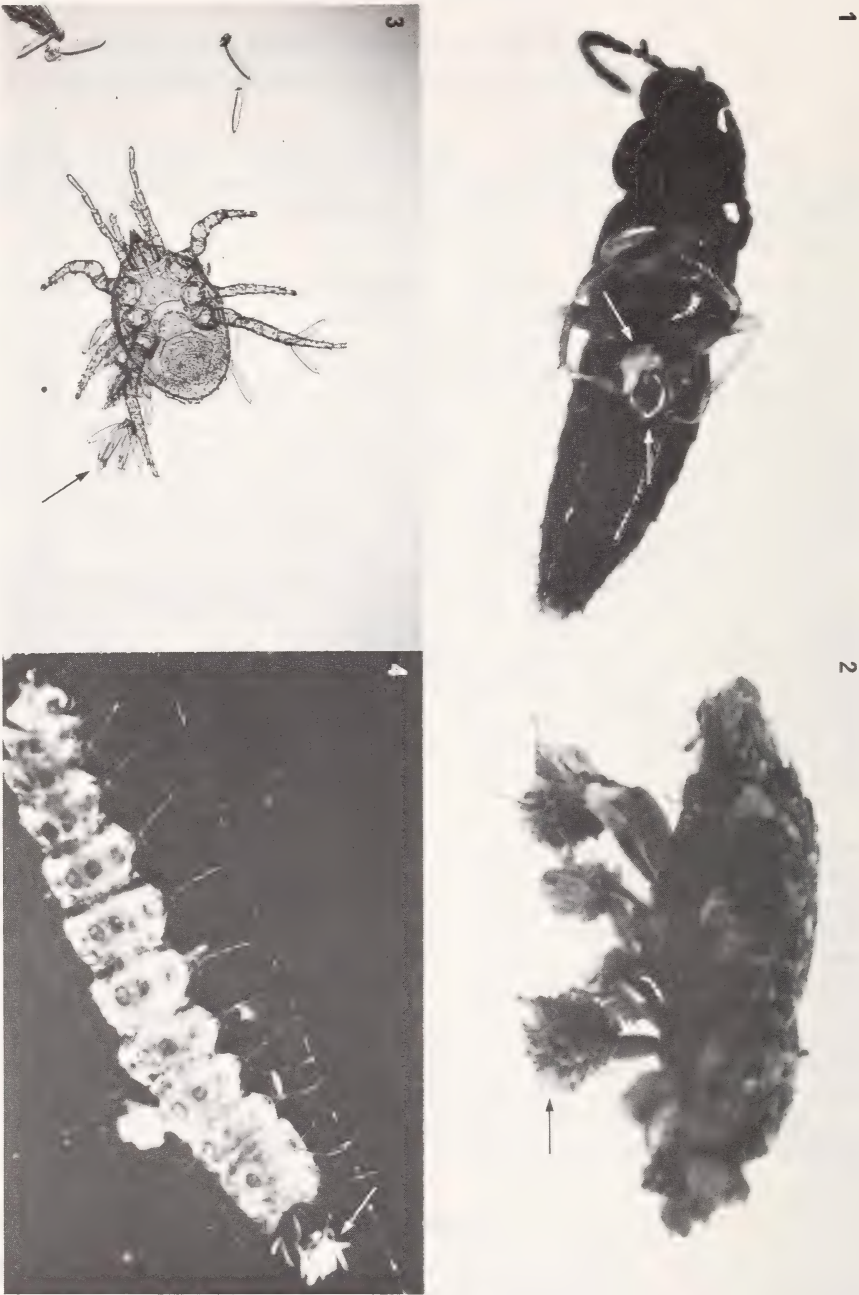
Figs. 1-4 show examples of phoretic nematodes on their hosts. The nematode is *Pelodera* sp. (Rhabditidae). Fig. 1 shows the unusual case of several nematodes phoretic upon a mite (Acari: Astigmata) which itself is phoretic upon a rove beetle (Coleoptera: Staphylinidae). In Fig. 2, a sap beetle (Coleoptera: Nitidulidae) is nearly covered with "dauer" nematodes, and its tibia and tarsus have large clumps of attached nematodes. A similar, but less severe condition is shown by a mesostigmatid mite in Fig. 3. In Fig. 4 the nematodes are attached to the head capsule of a larva of *Forcipomyia* (Diptera: Ceratopogonidae).

Völkl (1950) suggested that the phoretic relationship of nematodes with arthropods allows their dispersal and he observed encysted nematodes (*Pelodera cystilarva*) on unidentified mites and *Necrophorus vespilloides* (Coleoptera: Necrophoridae). Laurence (1954) observed dauer larvae on unidentified mites, *Aphodius* sp. (Coleoptera: Scarabaeidae), *Sepsis puparia* (Diptera: Sepsidae), and *Forcipomyia* larvae. Poinar (1964) observed a similar phenomenon with *Macrocheles glaber* (Mesostigmata: Macrochelidae) and suggested the relationship between nematodes and mites is a dispersal mechanism for the nematodes which may be a food source for the mites. He also suggested that the encysted larvae appear when the food supply for the nematodes fails or there is an increase in the concentration of excretory products from overcrowding.

Our observations have expanded the diversity of records of phoretic nematodes to Staphylinidae, Nitidulidae and possibly Astigmata.

Acknowledgments

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Figs. 1-4. Encysted nematodes (arrow) phoretic upon arthropods. 1, on an asitmatid mite (right arrow) which was phoretic upon a staphylinid, 14X, Bradford, Ont., 1 Oct. 1980. 2, on sap beetle *Carpophilus marginellus* (Molschulsky), 6X, Keswick, Ont., 11 Aug. 1980. 3, on a mesostigmatid mite, *Macrocheles* sp., 18X, London, Ont., 11 Sept. 1979. 4, on a larva of *Forcipomyia* sp. 22X, London, Ont., 19 Sept. 1980.

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CHROMOSOMAL CHARACTERIZATION OF CELL LINES OF *NEODIPRION LECONTEI* (HYMENOPTERA: DIPRIONIDAE)

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The redheaded pine sawfly, *Neodiprion lecontei* (Fitch), is an economically important pest of young pines in eastern Canada and the U.S.A. (Wilson and Reeks 1967). To facilitate study of a nuclear polyhedrosis virus that is very virulent for this sawfly (Bird 1961), ten sawfly cell lines were isolated from embryonic tissues. We have undertaken a chromosomal study of these cell lines to confirm their sawfly origin, and to determine whether or not they could be distinguished from each other on the basis of their chromosome complement. There are several reports (Herrick *et al.* 1970; Greene *et al.* 1972) of incorrect identification of vertebrate and insect cell lines because of cross contamination and/or mislabeling. We carry several lepidopteran cell lines which could be a source of contamination for new cell lines. Chromosomal characteristics of the lepidopteran cell lines have been reported previously (Ennis and Sohi 1976). In this note we analyze the chromosomal complement of the sawfly cell lines.

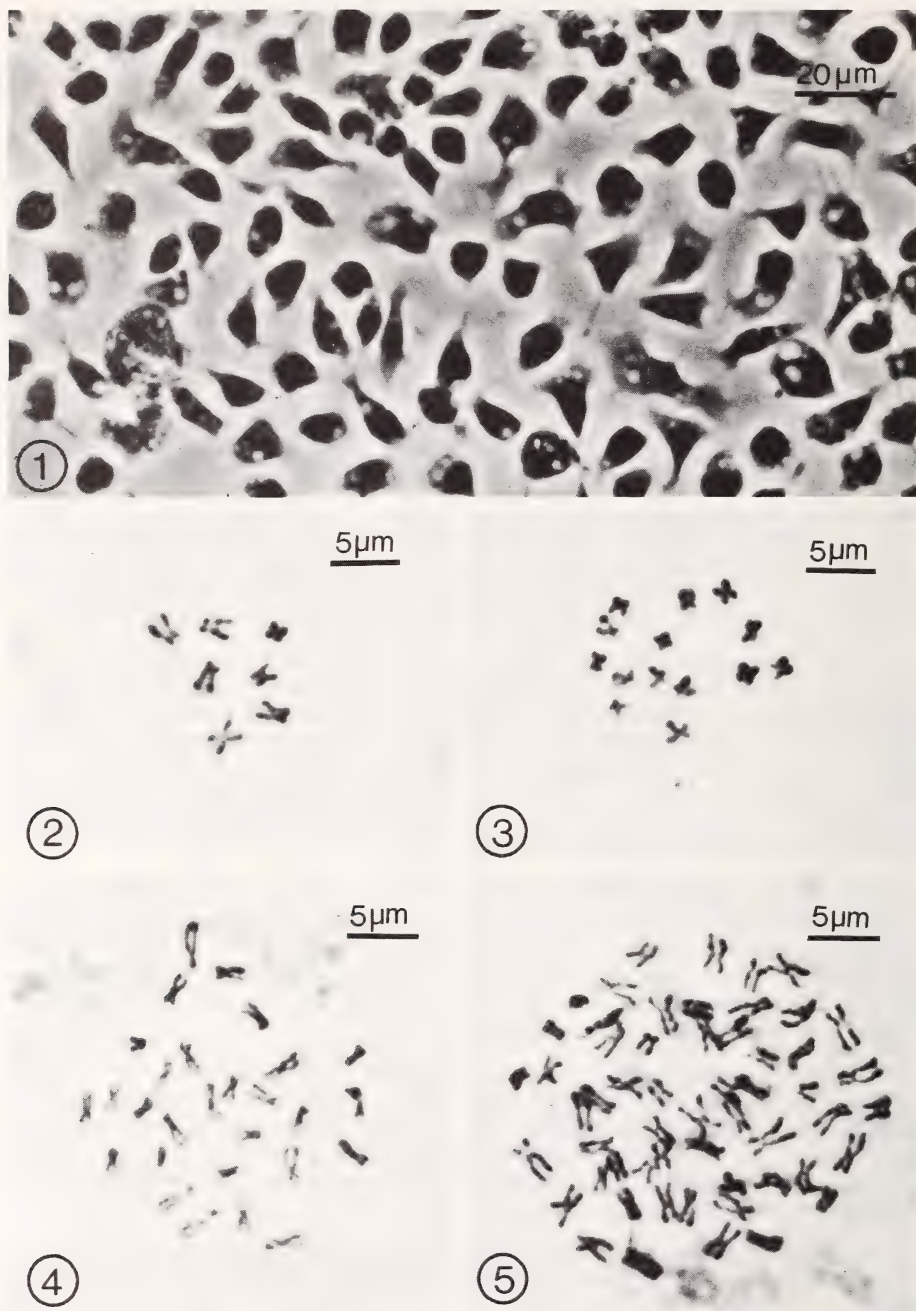
Pupae of *N. lecontei* were collected from the field and reared to the adult stage in the laboratory. Embryos from eggs laid by mated females were used to initiate the cell lines. Cultures were derived from embryonic tissues of *N. lecontei* using procedures described earlier (Sohi 1968). Grace's medium for insect tissue culture (Grace 1962) supplemented with 15% v/v fetal bovine serum and 0.25% w/v tryptose broth was used. Gentamicin at 50 µg/ml was added to the medium in all primary cultures and early passages of the cell lines. Cells were cultured at 28°C in 25-cm² Falcon plastic tissue culture flasks.

Cultures in logarithmic phase of growth were treated for 5 h with colchicine at a final concentration of 0.02 µg/ml. This was followed by 6 to 8 min in a 1% aqueous solution of sodium citrate, pelleting, fixation in 3 changes of acetic acid: methanol (1:3), air drying on slides and staining with aceto-carmine. A sample of 50 metaphase spreads was counted from NL-31, and 25 spreads were counted from each of the other cell lines.

The cell lines have been designated as FPMI-NL-1, -2, -4, -10, -18, -21, -22, -27, -28, and -31, and are referred to as NL-1, -2, etc. in this report. A typical culture of NL-1 cells is illustrated in Fig. 1. The cells are strongly attached to the culture flask and must be trypsinized to dislodge them for subculturing. The cells are of various shapes and sizes. Some are round and others are irregularly shaped with two or more cytoplasmic extensions.

The male of *N. lecontei* is haploid with seven chromosomes, and the female is diploid with 14. The chromosomes are about the same size and have distinct centromeres (Smith 1942; Maxwell 1958). Metaphase spreads of cells grown *in vitro* with 7, 14, 28 and 56 chromosomes are illustrated in Figs. 2-5. These figures show that all the chromosomes have distinct centromeres and most of them are about the same size, thus conforming to typical *N. lecontei* chromosomes.

Total time *in vitro*, passage number, modal chromosome number and range



FIGS. 1-5. Chromosomes of *Neodiprion lecontei* cells grown *in vitro*. 1, a live, unstained monolayer of NL-1 cells after 155 days *in vitro*. Bright phase contrast. 2-5, Colchicine mitoses of cell lines. 2, NL-31 with seven chromosomes representing the male haploid complement. 3, NL-10 with the diploid 14 chromosomes. 4, NL-31, a tetraploid with 28 chromosomes. 5, NL-31 with 56 chromosomes showing octoploidy.

TABLE I. Chromosomal characteristics of *Neodiprion lecontei* cell lines.

Cell line (FPMI-NL)	Passage	Total time <i>in vitro</i> (months)	Chromosome number*		Chromosome Numbers %			
			Mode	Range	7-9	10-19	20-36	45-56
4	8	15	14	11-28	0	96	4	0
10	10	12	14	7-28	8	80	12	0
27	9	11	14	7-28	8	80	12	0
21	11	12	14, 28	12-30	0	52	48	0
28	13	11	14, 28	10-47	0	40	56	4
31	15	11	14, 28	10-56	0	46	50	4
18	9	15	14, 28	12-55	0	68	24	8
22	18	11	14, 28, 49	12-49	0	32	16	52
2	12	12	14, 28, 49	11-80	0	48	20	28
1	26	27	24-27	17-55	0	4	80	16

*Based on 50 metaphase spreads from NL-31 line, and 25 spreads from each of the other lines.

for each cell line are given in Table I. All the cells examined in the 10 cell lines, except NL-2, had chromosome numbers between 7 to 56. Even NL-2 had fewer than 5% of the cells with more than 56 chromosomes, and the highest chromosome number encountered was 80. NL-4, -10 and -27 are essentially diploid and have a modal chromosome number of 14. In NL-10 and NL-27, about 5% of the cells had a chromosome number of 7, equal to that found in the haploid male.

In NL-18, -21, -28 and -31, chromosome numbers were clearly bimodal at 14 and 28, equivalent to diploidy and tetraploidy. NL-2 and NL-22 had clear modes at 14 and 28, but also had a significant percentage of cells with 45 to 56 chromosomes. NL-1 was somewhat exceptional in that no clear modal numbers occurred. Eighty percent of numbers fell in the range of 20 to 36 with most frequent numbers being 24 and 27. Only two cells contained an integral multiple of the base number 7; these were tetraploid at 28. The reason for this anomalous condition is not clear, but this line may be mitotically unstable. Thus, all the sawfly cell lines but one have modal chromosome numbers that are integral multiples of 7 for *N. lecontei*. On the other hand, the chromosomes of lepidopteran cell lines lack a distinct centromere and the two chromatids look like parallel rods. Moreover, the chromosome number of lepidopteran cell lines is much higher than that observed in the *N. lecontei* cell lines, and most of them are microchromosomes (Ennis and Sohi 1976).

In our laboratory, we are not carrying any cells other than the lepidopteran and sawfly cell lines and, as mentioned above, the chromosomes of the lepidopteran cell lines are very different in morphology and number from the chromosomes of the sawfly lines. Moreover, all the sawfly cell lines but one have modal chromosome numbers that are integral multiples of 7 for *N. lecontei*. Therefore it appears certain that these cell lines are indeed derived from *N. lecontei* tissues. However, no good criteria were found for distinguishing the individual sawfly cell lines from each other by chromosome number alone, although they could be distinguished into four groups. Three are unimodal at 14, four are bimodal at 14 and 28, two are trimodal at 14, 28 and 49, and one lacks a clear modal number, most frequent numbers being 24 and 27.

Acknowledgments

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**DAMAGE TO ASPARAGUS BY TARNISHED PLANT BUGS,
LYGUS LINEOLARIS, AND ALFALFA PLANT BUGS,
ADELPHOCORIS LINEOLATUS (HETEROPTERA: MIRIDAE)**

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Plant bugs are noted for their destructive feeding habits on a wide variety of crops. Their preference for feeding on meristematic tissues found in apical buds, seed pods, fruit and rapidly growing foliage or stems produces characteristic symptoms and damage. The nature of their feeding injury has been reviewed by Tingey and Pillemer (1977). Wild and cultivated host plants promote populations which may disperse to neighboring crops at a critical stage of growth (McEwen and Hervey 1960; Craig 1963; Khattat and Stewart 1980). Damage to asparagus spears by plant bugs is described for the first time in this study.

In a 1978 survey of asparagus production throughout Canada, plant bugs, particularly the tarnished plant bug, *Lygus lineolaris* (P. de B.), were associated with injury to this crop. Plant bugs were often observed feeding on fern and spears during late July, August, and early September. When spears were attacked just after emergence, the distal portion of a spear initially became wilted, producing a water-soaked, olive-green color. These spears eventually shrivelled, turned dark brown, and either desiccated or rotted due to secondary bacteria and *Botrytis cinerea* Pers. Frequently, after spears had branched out, terminal buds were destroyed by feeding of plant bugs and growth from axillary buds caused rosetting of fern branches. Plant bug nymphs and adults were often found within this 'witches-broom' (Tiessen *et al.* 1978).

Most growers regarded injury to fern late in the growing season as inconsequential. However, several growers reported losses due to spear withering in May during the harvest season in 1978 through 1981. On 30 May 1981, damaged spears were examined in a field near Chatham, Ontario. Injury occurred randomly throughout the field, affecting one to several spears per crown. Damage was neither correlated with frost conditions nor did affected spears have the typical dark, water-soaked symptoms of frost injury. Instead, affected spears withered, turned brown, and curved downwards above the soil surface, while stem tissue below ground was still turgid. Nymphs of the tarnished plant bug and the alfalfa plant bug, *Adelphocoris lineolatus* (Goeze), were found throughout this field.

Several damaged and undamaged crowns were taken from this field for further analysis. Sections of the tissue were dissected, surface sterilized in 1% sodium hypochlorite for 5 minutes, rinsed in sterile distilled water, and placed on potato dextrose agar. After incubation at 21°C for 7 days, colonies of *Fusarium moniliforme* Sheld. emend. Snyder & Hans. and *F. oxysporum* (Schlecht.) emend. Snyder & Hans. f.sp. *asparagi* Cohen appeared on sections from both healthy crowns and those affected by spear dieback. Although both of these pathogens can cause spear collapse (Cohen and Heald 1941; Johnston *et al.* 1979), we did not consistently find an association of *Fusarium* spp. infection with spear injury.

Adults and nymphs of the alfalfa plant bug were collected from an asparagus field on 17 June 1981, and caged on a healthy asparagus crown. Two adults and 6 nymphs were introduced on 18 June. Another crown was caged so as to exclude

TABLE I. Injury caused by tarnished plant bugs, *Lygus lineolaris*, on asparagus spears 36 hrs and 6 days after adults were caged on healthy crowns.

No. of Plant Bugs /cage	No. of Spears ¹			
	Aug. 7		Aug. 12	
	Healthy	Injured	Healthy	Injured
0	5.4 a	0 a	7.0 a	0.1 a
1	4.7 a	0.1 a	7.4 a	0.3 a
3	4.4 a	0 a	5.6 a	0.9 ab
5	5.6 a	1.0 a	6.7 a	1.9 b

¹ Means in each column followed by the same letter are not significantly different ($P = 0.05$), Duncan's Multiple Range Test.

all bugs. By 25 June, all spears in the infested cage had collapsed, whereas none in the uninfested cage showed symptoms. Small feeding punctures were observed on the curved side of affected spears at or below the point of injury. No stem breakdown was observed below the soil line.

The number of plant bugs necessary to produce injury was determined in a similar experiment at the University of Guelph Horticulture Research Station, Cambridge, Ontario. Asparagus fern (cv. Viking 2K) was mowed and, several days later, cages were placed over a single crown with emerging spears. Adult tarnished plant bugs collected from alfalfa were placed in each cage at densities of 0, 1, 3 and 5 bugs per cage on 6 August 1981. Treatments were replicated 7 times. On 7 August, all spears were examined for symptoms of feeding (Table I). Some spears were damaged in the cages which had 5 bugs per crown, but there was no significant difference between injured spears in these cages and those in other treatments after 36 hours. Because few bugs had survived in the cages, the same numbers were added on 8 August. Spears in all cages were examined again on 12 August. Spear collapse and deformation occurred in all treatments infested with plant bugs, but the number of spears damaged was highly variable. Significant injury was observed when 5 bugs were added per cage. At this level of infestation 22% of the spears were withered or malformed.

Evidently, symptoms of asparagus dieback during harvest are related to feeding by plant bugs. The cause of damage, whether through disruption of physiological processes or reaction to a toxin, is not clear. Perhaps fungi, *Fusarium* spp., which are present in the crown in association with feeding by plant bugs, are also a factor, but symptoms did not consistently appear when only fungi were present.

Acknowledgments

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**LABORATORY AND FIELD STUDIES ON THE EFFECTIVENESS AND
PERSISTENCE OF THREE PYRETHROID INSECTICIDES USED TO
CONTROL THE DARKSIDED CUTWORM,
EUXOA MESSORIA (LEPIDOPTERA: NOCTUIDAE)**

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Abstract

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Three experimental pyrethroid insecticides were tested under laboratory and field conditions to determine their efficacy and persistence when used to control the darksided cutworm, *Euxoa messoria* (Harris), attacking tobacco. Deltamethrin, BAY FCR 1272 ((RS)- α -cyano-4-fluoro-3-phenoxybenzyl (IRS)-*cis*, *trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate), and AC 222,705 ((RS)- α -cyano-3-phenoxybenzyl (S) - 2-(4-difluoromethoxyphenyl) - 3 - methylbutyrate) were all at least as toxic as permethrin by direct contact to 3rd-instar cutworms; all were more toxic than chlorpyrifos. Commercial EC formulations of the three pyrethroids, applied as surface applications on moist Plainfield sand, were at least as effective against 4th- to 5th-instar cutworms as formulated permethrin. Deltamethrin and BAY FCR 1272 were less toxic to cutworms on air-dry as compared to moist soil. Each material remained toxic on moist soil, even at the lowest application rates tested, for at least seven days. In microplot field tests done under very dry soil conditions, neither the experimental pyrethroids nor permethrin provided acceptable cutworm control after 24 h. Following irrigation with 0.25 cm water, permethrin applied at 70 g AI/ha provided effective cutworm control in 48 h, while deltamethrin, BAY FCR 1272, and AC 222,705 were as effective at 10, 25, and 50 g AI/ha, respectively. No insecticide residues were detected in tobacco harvested 80 days after application of deltamethrin, BAY FCR 1272, and AC 222,705 at 50 g AI/ha.

Introduction

Numerous species of cutworms damage agricultural crops. In southwestern Ontario the darksided cutworm, *Euxoa messoria* (Harris), is most important, attacking tobacco and vegetable crops grown on light mineral soils. Several organophosphorus insecticides have shown promise for cutworm control, but few have been registered or recommended for use. Chlorpyrifos, registered in some countries, is one of the few insecticides effective for subterranean cutworm control. Pertinent literature on cutworm control has been reviewed elsewhere (Harris *et al.* 1978). Harris *et al.* (1974, 1977, 1978) reported that some pyrethroid insecticides, including permethrin, cypermethrin, fenvalerate, and fenpropanate, were more effective than chlorpyrifos for the control of several cutworm species and subsequent studies have given equally promising results (Cheng 1979, 1980 a, b; Marmor *et al.* 1981; McDonald 1981 a, b). Permethrin and cypermethrin have been registered in Canada for control of several cutworm species on some crops. Currently other pyrethroid insecticides are being developed. We report here results of laboratory and field tests on the efficacy and persistence of three of these insecticides when tested for control of the darksided cutworm.

Materials and Methods

Rearing and bioassay procedures have been described by Harris *et al.* (1971, 1973 a, b) and will be referred to only briefly. Cutworms for all tests were obtained from a culture maintained at this laboratory.

Laboratory Studies. *Primary Screening.* Tests were done using 3rd-instar darksided cutworms. Insecticides (technical grade) tested were deltamethrin, BAY FCR 1272 ((RS)- α -cyano-4-fluoro-3-phenoxybenzyl (1 RS)-*cis, trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate) and AC 222, 705 ((RS)- α -cyano-3-phenoxybenzyl (S)-2-(4-difluoromethoxyphenyl)-3-methylbutyrate). Permethrin and chlorpyrifos were included for comparison. Insecticides were dissolved in 19:1 acetone:olive oil (v/v). Solvent controls and insecticide solutions (0.0001, 0.001, 0.01, 0.1 and 1.0%) were applied using a Potter spray tower (Potter 1952). Two replicates, each containing 10 larvae, were tested at each dosage. Treated insects were placed in containers half-filled with moist sand, and food was provided. The containers were covered with glass lids and held at $27 \pm 1^\circ\text{C}$ and $65 \pm 5\%$ RH, under continuous light, for 48 h, when mortality counts were made. Results were corrected for natural mortality (never $> 10\%$) (Abbott 1925) and expressed as the average of the two bioassays.

Secondary Screening. Initial tests of the effectiveness of EC formulations of the three experimental insecticides, as compared to an EC formulation of permethrin, were carried out as follows: Six kg of moist (6.0% water) Plainfield sand were placed in clean metal trays, 43 cm square x 10 cm deep. Two replicates, each consisting of 10, 4th- to 5th-instar larvae were placed on the soil in each tray and were covered with a plastic cage (Harris *et al.* 1973a). As soon as the cutworms burrowed beneath the soil, the cages were removed and the formulated insecticide was applied to the soil surface in 400 liters of water/ha, using a modified chromatography sprayer (Harris and Svec 1970). A food source was added, the cages were replaced, and the trays transferred to a holding room maintained at $21 \pm 1^\circ\text{C}$, $50 \pm 5\%$ RH, and 12-h photoperiod. Untreated control trays were included in all tests. Mortality counts were made after 24 or 48 h. Results were corrected for natural mortality (never $> 10\%$) (Abbott 1925), and are expressed as the average of the two bioassays.

Additional studies on deltamethrin and BAY FCR 1272 were carried out comparing effectiveness on moist (6.0% water) and air-dried (0.5% water) Plainfield sand. Persistence of activity of surface deposits was tested by confining two replicates of 10, 4th- to 5th-instar cutworms on undisturbed Plainfield sand seven days after initial insecticide application.

Field Studies. The effectiveness of EC formulations of the three pyrethroid insecticides as compared to permethrin, as preplanting applications to the soil surface, was assessed in microplots (Harris *et al.* 1971, 1973 a, b) containing Plainfield sand. On 19 May, two replicates of 10, 4th- to 5th-instar larvae were established in each microplot as described for the secondary screening tests. Once the larvae had burrowed beneath the soil, insecticides were applied at 135 kPa in 450 liters of water/ha with a single-nozzled (8002-flat fan) Oxford Precision Sprayer. Each treatment, including controls, was replicated twice in a randomized complete block design. Interim mortality counts were made after 24 h on 20 May. Due to the very dry weather, 0.25 cm of water was then applied to each microplot. There was no additional rainfall during the experiment. Maximum temperatures recorded during the 72 h following insecticide application were 26°C in the air, 31°C at the soil surface, and 30°C at the 2.5-cm depth. Final mortality counts were taken after 72 h. Results were corrected for natural mortality (never $> 10\%$) (Abbott 1925) and are expressed as the mean $\pm$ standard error of the four replicate bioassays of each treatment. Treatment means were compared by ANOVA and Duncan's Multiple Range test.

Delhi 76 tobacco was transplanted in all plots on 26 May.

TABLE I. Direct contact toxicity of three experimental pyrethroid insecticides to 3rd-instar darksided cutworms, as compared to permethrin and chlorpyrifos.

Insecticide	48-h avg corrected % mortality at indicated % insecticide solution				
	0.0001	0.001	0.01	0.1	1.0
Deltamethrin	10	100	100	100	100
BAY FCR 1272	0	95	100	100	100
AC 222, 705	0	15	100	100	100
Permethrin	0	15	100	100	100
Chlorpyrifos	0	0	55	100	100

Residue Studies. Tobacco was harvested from the plots on 7 August. Ten top, middle, and bottom leaves were selected at random from the 10 tobacco plants grown in the two microplots receiving identical insecticide treatment. After washing with cold water to remove adhering soil, leaves were halved lengthwise and one half was cut into ca. 2 x 2-cm pieces. A 200-g sample of pieces was selected for extraction. Extraction and subsequent cleanup were done as described by Chapman and Harris (1978), including a 2nd extraction of plant material. Extracts were analyzed by glc using a 120-cm x 4-mm ID glass column packed with 1% OV-101 on 100- to 120-mesh Gas Chrom Q operated isothermally at 250°C, with nitrogen as carrier gas flowing at 70 mL/min. The column extended through the injection port (180°C) to provide an integral glass liner and this portion was not packed. The ⁶³Ni electron capture detector was maintained at 320°C. Quantitation was by peak height using suitable concentrations of external standards. Under these conditions, the retention times were: BAY FCR 1272, 11.3 min (skewed peak for eight isomers); AC 222,705, 13.0 and 14.4 min (double peak for two diastereoisomers); and deltamethrin, 21.9 min, as compared with permethrin at 9.2 min. Recoveries of 1.0 and 0.01 ppm insecticide added at

TABLE II. Effectiveness, under laboratory conditions, of three experimental pyrethroid insecticides and permethrin applied as soil surface applications to Plainfield sand for control of 4th- to 5th-instar darksided cutworms.

Insecticide	Formulation	Days post application*	48-h avg. corrected % mortality at indicated g AI/ha				
			4.375	8.75	17.5	35.0	70.0
MOIST (6% WATER) SAND							
Deltamethrin	2.5 EC	0	100	98	95	100	
		7	100	85	100		
BAY FCR 1272	200 E	0		100	98	100	100
		7		95	100	100	
AC 222,705	300 EC	0			90	95	100
Permethrin	50 EC	0				100	95
AIR-DRY (0.5% WATER) SAND							
Deltamethrin	2.5 EC	0	15	5	25		
		7	0	16	32		
BAY FCR 1272	200 E	0		0	25	25	
		7		0	0	0	

* Days after treatment when larvae were introduced into the soil.

the extraction step were 93 and 93% for BAY FCR 1272; 102 and 108% for AC 222, 705; and 84 and 78% for deltamethrin.

Results and Discussion

Laboratory Studies. In the primary screening tests, the three experimental pyrethroids were all more toxic by direct contact to 3rd-instar darksided cutworms than chlorpyrifos (Table I). They were at least as toxic as permethrin, with deltamethrin being most toxic > BAY FCR 1272 > AC 222,705 = permethrin.

In the secondary screening tests on moist Plainfield sand, deltamethrin, BAY FCR 1272, and AC 222,705 were at least as effective as permethrin, when applied as soil surface applications, against 4th- to 5th-instar darksided cutworms (Table II). Indeed, under these conditions deltamethrin and BAY FCR 1272 at 4.375 and 8.75 g AI/ha, respectively, caused 100% mortality of the 4th- to 5th-instar larvae in 48 h. Lower application rates were not tested. These two pyrethroids remained toxic, even at the lowest application rates tested for at least seven days. Both deltamethrin and BAY FCR 1272 were less active in air-dry soil, as shown previously for several other pyrethroid insecticides (Harris *et al.* 1978; Harris and Turnbull 1978). Higher field application rates on dry soil, as currently recommended for permethrin and cypermethrin (Anonymous 1981), may also be necessary for deltamethrin and BAY FCR 1272.

Field Studies. Under the dry conditions prevailing at the time of insecticide application, no insecticide provided acceptable control of the cutworms after 24 h

TABLE III. Effectiveness, in field tests, of three experimental pyrethroid insecticides and permethrin applied as soil surface applications to Plainfield sand for control of 4th- to 5th-instar darksided cutworms.

Insecticide	Formulation	Rate of application (g AI/ha)	Avg. corrected % mortality $\pm$ S.E.*	
			24 h	72 h
Deltamethrin	2.5 EC	10	22.5 bcd $\pm$ 4.8	79.5 a $\pm$ 7.3
		25	32.5 bc $\pm$ 10.3	87.2 a $\pm$ 4.9
		50	55.0 a $\pm$ 9.6	100.0 a $\pm$ 0.0
BAY FCR 1272	200 E	25	20.0 cd $\pm$ 9.1	82.1 a $\pm$ 12.1
		50	42.5 ab $\pm$ 6.3	92.3 a $\pm$ 2.6
AC 222,705	300 EC	25	5.0 d $\pm$ 2.9	48.7 b $\pm$ 15.1
		50	15.0 cd $\pm$ 6.5	87.2 a $\pm$ 6.5
Permethrin	50 EC	70	22.5 bcd $\pm$ 11.1	89.7 a $\pm$ 4.2
Control	—	—	0.0 d	0.0 c

* Means in each column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test. Corrected mortalities at the two sampling periods were analyzed separately.

(Table III). The highest rate of deltamethrin (50 g AI/ha) gave significantly better control than the commercial standard, permethrin, applied at the recommended rate of 70 g AI/ha, while deltamethrin, BAY FCR 1272, and AC 222,705 were as effective at 10, 25, and 50 g AI/ha, respectively. After overhead irrigation (0.25 cm water) and a further 48 h, all insecticides provided excellent cutworm control with the exception of the 25 g AI/ha rate of AC 222,705.

Residue Studies. No residues (sensitivity of method 0.01 ppm) were detected in the tobacco harvested 80 days after application of deltamethrin, BAY FCR 1272, and AC 222,705 at the 50 g AI/ha treatment level.

Conclusions

These results indicate that deltamethrin, BAY FCR 1272, and AC 222,705 are at least as effective as permethrin against darksided cutworm and thus have excellent potential for cutworm control. Under optimum conditions of high soil moisture, they would be effective at rates $\leq$ 50 g AI/ha, while higher application rates would be required on dry mineral soils. At an application rate of 50 g AI/ha, insecticide residues at harvest would be < 0.01 ppm.

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**THE PARASITE COMPLEX OF THE OVERWINTERING POPULATION
OF *EPIBLEMA SCUDDERIANA*
(LEPIDOPTERA: OLETHREUTIDAE)
IN SOUTHERN ONTARIO**

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Abstract

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The parasite complex of the overwintering population of *Epiblema scudderiana* (Clemens) (Lepidoptera: Olethreutidae), a gall-inducing insect on goldenrod, was studied during 1977-78, 1979-80 and 1980-81 in Guelph, Ontario. *Dolichogenidea* (= *Apanteles*) *cacoeciae* Riley, *Macrocentrus pallisteri* DeGant, *Agathis binominata* Mues. and *Scambus pterophori* (Ashm.) parasitized *E. scudderiana*. *Perilampus fulvicornis* (Ashm.) was a hyperparasite of all of the primary hymenopteran parasites.

Life tables, constructed for the overwintering population of *E. scudderiana* for each year of this study, showed that the major mortality factors for this species during the overwintering period were desiccation of the pupae and parasitism by *M. pallisteri*. It is suggested that *M. pallisteri* is the mortality factor responsible for considerable fluctuations observed from year to year in the population of *E. scudderiana*.

Introduction

The larvae of *Epiblema scudderiana* (Clemens) cause the formation of spindle-shaped galls on goldenrod, most frequently *Solidago altissima* L. and *S. canadensis* L. (Miller 1971). *E. scudderiana* overwinter as prepupae within these galls and emerge in late May or early June through a previously prepared exit. Adults then mate and oviposit on young plants and each successful oviposition may result in the formation of a gall. Eggs hatch in late June, larvae feed in the terminal buds for a short time then bore into the stem and, through the action of feeding, cause the formation of the characteristic galls (Miller 1971).

A number of mortality factors are known to affect *E. scudderiana*. Bird predation has been cited as a major mortality factor affecting another taper gall former, *Gnorimoschema gallaesolidaginis* Riley (Barber 1938), and *Eurosta solidaginis* Fitch, the goldenrod ball gall fly (Cane and Kurczewski 1976). Although not recorded in the literature, personal observations suggest that in the Guelph area, woodpeckers are a major mortality factor over the winter months for larvae of *E. scudderiana* in galls which remain exposed above the snow. Another major mortality factor affecting the entire population is the variety of primary parasites which have been reported to attack 11.12% of a population of *E. scudderiana* in Pennsylvania (Plakidas 1978).

Casual observations suggested that this species has considerable fluctuations in population density in the field from year to year. This study was conducted to determine the parasite complex of the overwintering population of *E. scudderiana* and its effect on the density of the host insect.

Materials and Methods

In mid January 1978, 635 galls of *E. scudderiana* were collected randomly from uncultivated fields at the University of Guelph Arboretum and from an area

south of the Arkell Research Station. Only undamaged galls or those above the snow cover and large enough to contain mature larvae were selected. The galls were placed individually in 16-dram plastic vials with a fine-mesh cloth cover and held in cold storage at 2°C. On 3 February 1978, the vials were placed in five controlled environment chambers at 12, 14, 17, 19 and 23°C, at 16 hL: 8hD and 70-90% RH. The galls were checked daily for emergence. All galls were later dissected and the contents identified. Numbers of insects emerging at the five temperatures were not different and the results from each of the chambers were combined.

In mid November 1979, 2,000 galls were collected from a field at the Guelph Arboretum and stored in an open-topped, wooden, apple crate in an outdoor compound. In early April, when snow cover was beginning to disappear, the crate was placed in cold storage at 2°C. The galls were removed from the crate, while in cold storage, and placed individually in 16-dr vials covered with fine-mesh gauze. On 10 June 1980, the vials were removed from cold storage and placed in a Conviron® growth chamber at 25°C and 16hL: 8hD. The contents of the vials were checked daily for emergence and after 10 weeks all galls were dissected and the contents identified.

In late April 1981, 722 galls were collected from the same field. The galls were dissected and the *Epiblema* larvae removed. The larvae were placed individually in 2.5-cm lengths of clear, plastic tubing (o.d. 3 mm) and reared at 25°C and 16hL: 8hD. The contents of the tubing were checked daily for emergence.

Results and Discussion

Overwintering Population of 1977-78. *E. scudderiana* emerged from 17% of the galls collected in the winter of 1978 (Table I). The 108 emerged moths had a sex ratio of 1:1. Of the 458 galls from which no insects emerged, 100 had unidentified contents, 36 contained parasites, and the remainder contained 111 desiccated pupae and 211 desiccated larvae of *E. scudderiana*. A total of 324 *E. scudderiana* developed past the early larval stages and, of these, 105 or 32.4% were parasitized. *E. scudderiana* were directly parasitized by the braconids *Dolichogenidea* (= *Apanteles*) *cacoeciae* Riley, *Macrocentrus pallisteri* DeGant, and *Agathis binominata* Mues. (= *bicolor* (Prov.)), as well as the ichneumonid, *Scambus pterophori* (Ashm.) (Table I).

A total of 328 cocoons of *D. cacoeciae*, a gregarious parasite when found in large hosts, were found in 36 galls and 280 adults emerged from these. This rate of parasitism (11.1%) is much higher than the 1.89% found by Plakidas (1978) in southwestern Pennsylvania. Judd (1950) reported high numbers of *D. cacoeciae* emerging from *G. gallaesolidaginis* (14% parasitism) in the Hamilton, Ontario area. However, it is possible that the galls of *E. scudderiana* were mistaken for those of *G. gallaesolidaginis* as, during the course of this study, no *D. cacoeciae* cocoons were found in the galls of *G. gallaesolidaginis*. The sex ratio of the emerged adults of *D. cacoeciae* was 1.8:1.0 females to males which agrees with the ratio found by Judd (1950). The number of pupae in each gall ranged from 3-18, with an average of nine. At all five temperatures, *D. cacoeciae* adults emerged prior to *E. scudderiana*, which suggests that an alternative host is required for these wasps until *E. scudderiana* is at an acceptable stage for parasitism. *D. cacoeciae* has been reported from *Acrobasis* sp., *Archips* spp., *Epinotia* sp., *Exartema* sp., *G. gallaesolidaginis*, *Sciaphila* sp., and *Tortrix* sp. (Krombein *et al.* 1979).

TABLE I. Life table of *Epiblema scudderiana* (Clem.) collected during the overwintering "dormant" period, Guelph, Ontario, 1977-1978.

	Observed			Corrected		
	Initial number	Fraction killed	% killed	Number killed	% killed	k value
Initial number of galls examined	635	—	—	—	—	—
Empty galls—unidentified contents	100	100/635	15.7	68	10.7	0.049
Larvae died in gall (reason unknown)	211	211/635	33.2	143	22.5	0.126
Parasitized by:						
<i>Dolichogenidea cacoeciae</i> (Riley)	36	36/324	11.1	70	11.1	0.078
<i>Macrocentrus pallisteri</i> DeGant	63	63/324	19.4	123	19.4	0.185
<i>Agathis binominata</i> Mues.	4	4/324	1.2	8	1.2	0.015
<i>Scambus pterophori</i> (Ashm.)	2	2/324	0.6	4	0.6	0.008
Total parasitism	105	105/324	32.4	205	32.3	0.286
Desiccated pupae	111	111/324	34.3	111	17.5	0.307
Emerged adults of <i>Epiblema scudderiana</i> (Clem.)	108	—	—	108	—	—

TABLE II. Life table of *Epiblema scudderiana* (Clem.) collected during the overwintering "dormant" period, Guelph, Ontario, 1979-1980.

	Observed			Corrected		
	Initial number	Fraction killed	% killed	Number killed	% killed	k value
Initial number of galls examined	2,000	—	—	—	—	—
Empty galls—unidentified contents	194	194/2,000	9.7	69	3.5	0.015
Larvae died in gall (reason unknown)	253	253/2,000	12.7	90	4.5	0.021
Parasitized by:						
<i>Dolichogenidea cacoeciae</i> (Riley)	75	75/1,553	4.8	96	4.8	0.023
<i>Macrocentrus pallisteri</i> DeGant	893	893/1,553	57.5	1,150	57.5	0.467
<i>Agathis binominata</i> Mues.	16	16/1,553	1.0	21	1.0	0.016
<i>Scambus pterophori</i> (Ashm.)	17	17/1,553	1.1	22	1.1	0.017
Total parasitism	1,001	1,001/1,553	64.4	1,289/2,000	64.4	0.523
Desiccated pupae	269	269/1,553	17.3	269	13.5	0.290
Emerged adults of <i>Epiblema scudderiana</i> (Clem.)	283	—	—	283	—	—

TABLE III. Life table of *Epiblema scudderiana* (Clem.) collected during the overwintering "dormant" period, Guelph, Ontario, 1980-1981.

	Observed			Corrected		
	Initial number	Fraction killed	% killed	Number killed	% killed	k value
Initial number of galls examined	722	—	—	—	—	—
Empty galls—unidentified contents	197	197/722	24.3	46	6.4	0.028
Larvae died in gall (reason unknown)	128	128/722	17.7			
Parasitized by:						
<i>Dolichogenidae cacociacae</i> (Riley)	32	32/397	8.0	30	4.1	0.020
<i>Macrocentrus pallisteri</i> DeGant	268	268/397	67.5	58	8.0	0.041
<i>Agathis binominata</i> Mues.	0	0/347	0.0	488	67.6	0.765
<i>Scambus pterophori</i> (Ashm.)	4	4/397	1.0	0	0	—
Total parasitism	304	304/397	76.6	7	1.0	0.031
Desiccated pupae	46	46/397	11.6	552	76.6	0.837
Emerged adults of <i>Epiblema scudderiana</i> (Clem.)	47	—	—	46	6.4	0.300
				47	—	—

TABLE IV. Hyperparasitism of the parasites of *Epiblema scudderiana* (Clem.) by *Perilampus fulvicornis* (Ashm.) at Guelph, Ontario, 1979-1980.

Host Species	1978-1979			1979-1980			1980-1981		
	No. hosts	No. attacked	% hyper.	No. hosts	No. attacked	% hyper.	No. hosts	No. attacked	% hyper.
<i>Dolichogenidae cacociacae</i> (Riley) *	328	25†	7.6	572	72††	12.6	242†††	—	—
<i>Macrocentrus pallisteri</i> DeGant	63	26	41.3	893	666	74.6	268	209	78.0
<i>Agathis binominata</i> Mues.	4	1	25.0	17	8	47.0	0	0	0
<i>Scambus pterophori</i> (Ashm.)	2	0	0	16	1	6.2	4	0	0

* gregarious parasite.
† 13 galls of a possible 36 galls contained *P. fulvicornis*.
†† 42 galls of a possible 75 galls contained *P. fulvicornis*.
††† 32 galls possible—parasitism by *P. fulvicornis* not recorded.

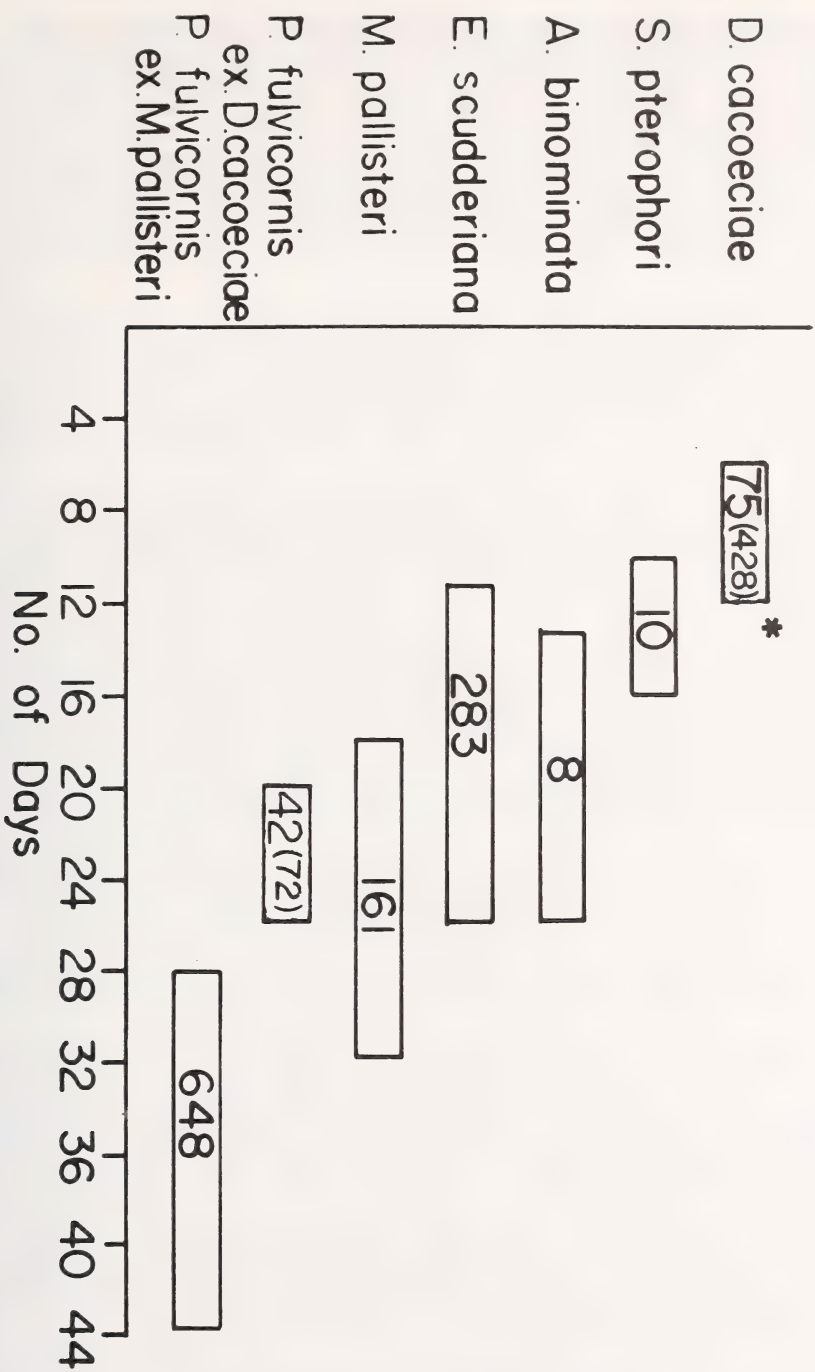


FIG. 1. Emergence of *Epiblema scudderiana* and parasites at Guelph, 1980, at 25°C, 16 hL: 8 hD. * = Number of galls with emergence and () = no. of individuals if more than one per gall.

Parasitism of *E. scudderiana* by *M. pallisteri* in 1978 accounted for 19.4% of the 324 galls that developed past the larval stage, a much higher rate than the 1.4% of Plakidas (1978). From the 63 *E. scudderiana* parasitized by *M. pallisteri*, only eight females emerged; 26 were hyperparasitized and 29 pupae were dead within the galls. *M. pallisteri* is a solitary parasite that forms an oblong, brown cocoon. It has also been recorded as a parasite of *Epiblemma obfuscum* Dyer, *E. otiosum* (Clem.), *E. strenuatum* (Wlkr.), *Grapholitha molesta* (Busck) and possibly *Ostrinia nubilalis* (Hbn.) (Krombein *et al.* 1979). No males were reared from the 1978 sample but were found in previous surveys.

A. binominata, a solitary parasite that forms a white, oblong cocoon, was reared for the first time from *E. scudderiana*. One female emerged successfully and one male was dissected from its cocoon. Two other cocoons of the same type were found; one was damaged during removal from the gall and the other hyperparasitized. *A. binominata* has been reported as a parasite of several species including *Choristoneura fumiferana* (Clem.) and *Rhyacionia buoliana* (Schiff.) (Krombein *et al.* 1979).

S. pterophori, which forms a naked pupa in the gall after overwintering in the host larva, successfully emerged from only two galls. Plakidas (1978) observed a higher rate of parasitism by *S. pterophori* (2.9%). No hyperparasites of this species were observed.

P. fulvicornis (Perilampidae) was a hyperparasite of 13% of the primary parasites of *E. scudderiana* and attacked all species of primary parasites except *S. pterophori* (Table IV). *P. fulvicornis* occurred in 40 separate galls, with multiple emergences from galls containing the gregarious parasite *D. cacoeciae*. *P. fulvicornis* hyperparasitized 25 *D. cacoeciae* in 13 galls out of a potential of 328 *D. cacoeciae* in 36 galls (Table IV). The highest number of *P. fulvicornis* emerging from one gall, initially containing *E. scudderiana* parasitized by *D. cacoeciae*, was six (4 ♀♀, 2 ♂♂), but only one *P. fulvicornis* per cocoon of *D. cacoeciae* was recorded. *P. fulvicornis* attacked 43% of the larvae of *M. pallisteri*. Those hyperparasitic upon *D. cacoeciae*, emerged earlier and were generally much smaller in size than the *P. fulvicornis* that emerged from the pupae of *M. pallisteri*. The pupae of *M. pallisteri* were larger and the adults emerged later than *D. cacoeciae*. *P. fulvicornis* was found in one cocoon of *A. binominata* and was not found in *S. pterophori*. *P. fulvicornis* has a wide host range of ichneumonoids with 18 species recorded in 13 different genera (Krombein *et al.* 1979).

Overwintering Population of 1979-80. Of the 2,000 galls taken in the fall of 1979, and kept over winter, *E. scudderiana* emerged from 14.2% or 22% of the 1,284 galls with successful emergence. The numbers dying as immature larvae and desiccated pupae were considerably lower in 1979-80 (Table II) than in 1977-78. The latter may reflect the difference in methods of holding the samples during the overwintering periods.

Parasites killed 64.4% of the larvae within the galls, approximately twice the rate of parasitism observed in 1977-78. The large increase in parasitism was due to *M. pallisteri* which successfully attacked 57.5% of the hosts. Parasitism by *D. cacoeciae* and *S. pterophori* declined to 4.8 and 0.6%, respectively, while that by *A. binominata* remained nearly constant at 1.2%.

P. fulvicornis was a hyperparasite of 12.6% of the *D. cacoeciae*, attacking 56% of 75 galls. Parasitism of *M. pallisteri* by *P. fulvicornis* increased from 1977-78 to 74.6% in 1979-80. Parasitism of *A. binominata* increased to 47% and one *P. fulvicornis* was recorded from *S. pterophori* (Ashm.).

Figure 1 shows the emergence pattern of *E. scudderiana* at a constant temperature of 25°C. As observed in 1978, the emergence of *D. cacoeciae* was earlier than the first emergence of *E. scudderiana*. The emergence of *P. fulvicornis* occurred over two distinct time periods which were dependent on the host parasite.

Overwintering Population of 1980-81. *E. scudderiana* emerged from only 6.5% of the 722 galls collected in the fall of 1980 or 11.8% of the 397 galls with successful emergence. The numbers dying as immature larvae increased from 22.4% in 1979-80 to 42.0% in 1980-81 and the numbers dying as pupae decreased to 11.6%.

Primary parasitism in 1980-81 increased to 76.6% of the larvae within the galls (Table III). The increase of 12.2% was due to *D. cacoeciae* and *M. pallisteri*. *S. pterophori* remained at the same low level and *A. binominata* was not found. Hyperparasitism by *P. fulvicornis* was again high with 78% of the 268 *M. pallisteri* being attacked (Table IV).

Life Tables. A life table for the overwintering period of 1977-78 of *E. scudderiana* is shown in Table I. This life table is similar to that of Varley *et al.* (1974) for the knapweed gallfly. Of 635 galls examined in 1978, 100 contained nothing or unidentifiable material, and 211 contained dead larvae, which left 324 to serve as observable hosts for parasites. Thus, 105 parasites came from 324 successful hosts for a rate of 32.3% parasitism. However, the empty galls and the galls containing desiccated larvae may have contained parasites and should be included as potential hosts. If we assume that the rate of parasitism for these 635 potential hosts was the same as the observed parasitism, then the life table can be 'corrected' to show the numbers attributable to each category of mortality. This correction does not change the percentage mortality due to parasitism but does change the numbers dying in each category. Since all of the parasites emerged from the larvae and non pupal parasites were observed, the 111 desiccated pupae could not have died of parasitism.

The killing power for each mortality factor in 1977-78 (k-value, which is the log of the numbers of hosts before the mortality factor occurs minus the log of the numbers of hosts after the mortality factor occurs) is given in Table I. The k-value for desiccated pupae is highest followed by the k-values for *M. pallisteri*, dead larvae and *D. cacoeciae* which shows that the parasites had a considerable effect on the overwintering population of *E. scudderiana* during 1977-78.

Life tables for the overwintering periods of *E. scudderiana* in 1979-80 and 1980-81 are presented in Tables II and III. Premature larval mortality remained low throughout the two overwintering periods. The k-value for larval mortality in fully formed galls was lower than in 1977-78 and may be attributed to improved methods of holding the galls over winter. The mortality represented by desiccation of the pupae remained constant over the three overwintering periods. However, while these mortality factors tended to either decrease or remain constant, there was a dramatic increase in the mortality due to parasitism with the k-values rising from 0.286 in 1977-78 to 0.837 in 1980-81. The major factor causing this increase was parasitism by *M. pallisteri*. The rise in mortality due to parasitism was followed by an increase in the hyperparasitism by *P. fulvicornis* (Table IV) from 1977-78 to 1980-81.

Mortality through desiccation of the pupae within the galls, while high, remained constant throughout the period of this study and added little to the fluctuation in numbers of *E. scudderiana*. *M. pallisteri* in turn appears to be

regulated by *P. fulvicornis*. The hyperparasite continues to maintain itself in high numbers in this system and possibly acts as a protective mechanism to prevent excessive numbers of primary parasites from emerging and drastically reducing the host population. This study shows an interesting balance in the interactions between host, parasite and hyperparasite which tends to maintain the host at low numbers within a field system which is essentially a monoculture of goldenrod. Parasitism by *M. pallisteri* is the key factor in the regulation of the population of *E. scudderiana* during the overwintering period.

Acknowledgments

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**DIFFERENCES IN THE NUMBERS OF SENSILLA TRICHODEA
BETWEEN REARED AND WILD ADULTS OF THE ORIENTAL
FRUIT MOTH, *GRAPHOLITHA MOLESTA*
(LEPIDOPTERA: TORTRICIDAE)**

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Abstract

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There were fewer sensilla trichodea on the antennae of adult males of the Oriental fruit moth from a colony reared in isolation for 20 years than on wild males. The difference was restricted to the scale-covered regions of the antennae. There were 59% fewer sensilla trichodea on the scale-covered regions of flagomeres 10-35 of laboratory-reared males than on the same regions of wild males while the numbers of sensilla in the scale-free regions were always comparable. After interbreeding wild insects with the laboratory colony, the numbers of sensilla on males from the laboratory colony were comparable to those of wild moths.

Based on this new information, it is postulated that the s. trichodea in the scale-covered regions of the antennae of males are the structures most likely responsible for the perception of female-produced pheromones. Furthermore, as the reduction in sensilla in laboratory-reared males may be correlated with a difference in mating performance, long term laboratory-reared insects cannot be assumed to be the same as their wild counterparts.

Introduction

There has often been concern that insects reared for prolonged periods in the laboratory may in some way be selected to differ from their wild counterparts in behaviour, physiology and even morphology. This possibility has become of critical importance with increased interest in the release of laboratory-reared, sterile adults, parasites or predators, to reduce crop losses (Smith 1966; Chambers 1977). Thus, any difference observed between reared and wild insects merits investigation.

In a survey of the types of sensilla (s.) on the antennae of adults of the Oriental fruit moth, *Grapholitha molesta* (Busck), the first specimens examined were from a laboratory colony that had been reared in isolation for 20 years. After wild specimens had been added to the colony, males had greater numbers of the most abundant sensilla, the s. trichodea, on their antennae than the first males examined (Nagy 1981).

Because of the importance of s. trichodea in pheromone perception in other moths (O'Connell 1975; Albert *et al.* 1974; Schneider 1969), we used a technique developed to remove scales and permit reliable counts of sensilla on the antennae (Nagy 1978) to compare the numbers and distribution of s. trichodea on adults from three sources: the wild, the laboratory colony before the addition of wild specimens and the laboratory colony after the addition of wild specimens.

Materials and Methods

Adults were reared from pupae obtained from the laboratory colony at Agriculture Canada Research Station, Vineland Station, Ontario in April 1977 (designated "Lab 1") and again in September 1979 (designated "Lab. 2") whereas wild adults (designated "wild") were reared from larvae collected from

peach twigs in an insecticide-free orchard near Vineland in 1978. Prior to 1979 the Vineland Laboratory colony had been reared without diapause on immature apples for about 20 years without the addition of wild insects. From May until October 1979, wild insects were added periodically to the Lab. 1 colony up to a total ratio of about one wild adult for every three in the laboratory colony (Pree, D. J., Agriculture Canada, Vineland Station, Ont., personal communication). The designation "Lab. 2", refers to insects from the Vineland Laboratory colony after the addition of wild insects. Hence the insects examined were from three sources or colonies: "Lab. 1", "Lab. 2" and "wild".

Upon emergence adults were anaesthetized with carbon dioxide, sexed, decapitated and the heads stored in 80% ethyl alcohol. Scales were removed and the antennae stained and mounted as described by Nagy (1978). Sensilla trichodea were counted with a light microscope and the total number for a single antenna was calculated from counts made on every fifth flagellomere of from five to 15 insects. The number of s. trichodea were also counted on the antennae of eight other males on flagellomeres located near the middles of the flagella. For each antenna two counts were made, one on the scaled region and one on the scale-free region of the same flagellomere. Counts on these two regions were made on males from each of the three colonies.

Results and Discussion

The antenna of both sexes of *G. molesta* are covered with scales except for a scale-free ventral longitudinal band (VLB) that extends the length of each flagellum (Fig. 1). The scale-free bands are ventral when the antennae are extended forward. The s. trichodea have a fixed base, taper to a point as they curve towards the distal ends of the antennae and occur all around the antennae in both the scaled and scale-free regions (Fig. 2). With scanning electron microscopy, no difference could be detected in sensilla between the two regions.

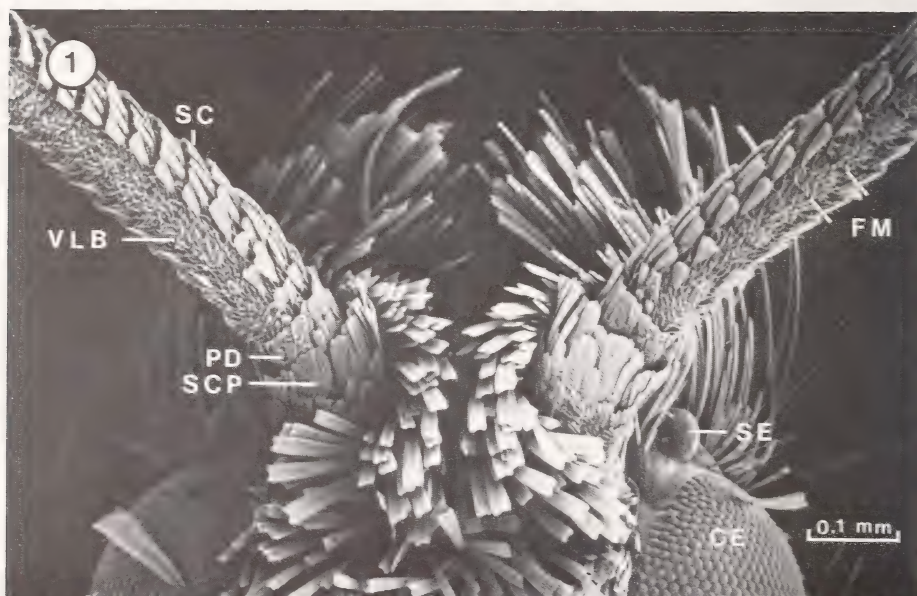


FIG. 1. Ventral view of bases of antennae of the Oriental fruit moth. CE, compound eyes; FM, flagellomere; PD, pedicel; SC, scale; SCP, scape; SE, simple eye; and VLB, scale-free ventral longitudinal band.



FIG. 2. Lateral view of scale-free ventral longitudinal band (VLB) and scaled region with some scales removed to show sensilla trichodea in both scaled (double arrows) and scale-free (single arrow) regions. SC, scale; and SAP, scale attachment pit.

3

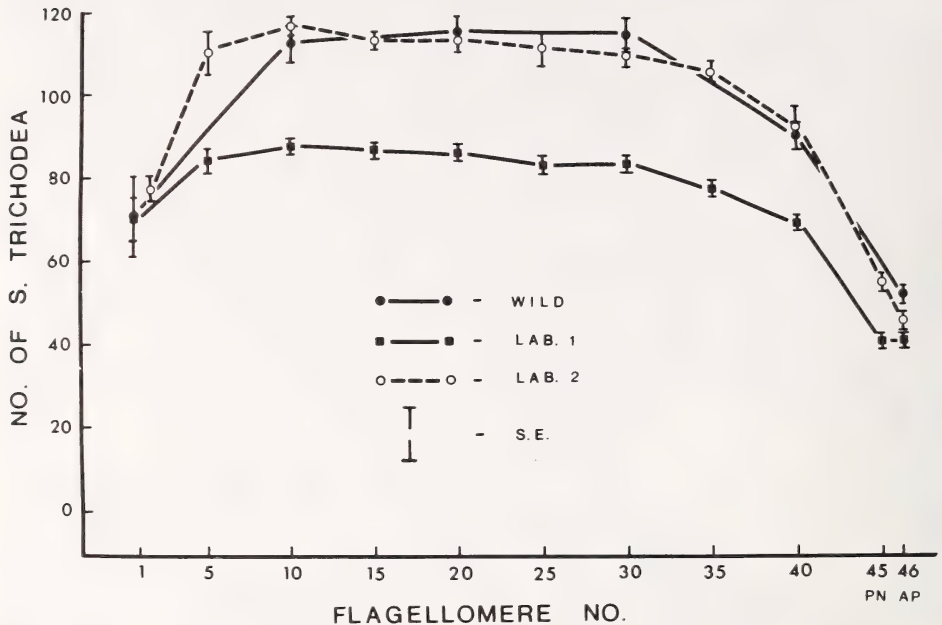


FIG. 3. Average numbers of sensilla trichodea on flagellomeres along the flagella of males from three sources. AP, apical flagellomere; PN, penultimate flagellomere; and S. E., standard error.

There were 24% less s. trichodea on the antennae of Lab. 1 males than on wild males, but there was no significant difference between Lab. 2 and wild males (Table I). Similarly, Lab. 1 females had 19% fewer wild females, whereas there was no significant difference between Lab. 2 and wild females. Females of the wild, Lab. 1, and Lab. 2 strains had, respectively, 40%, 36%, and 32% less s. trichodea than the respective males (Table I). Males of the Lab. 1 colony had about 25 fewer s. trichodea per flagellomere than either wild or Lab. 2 males (Fig. 3). This difference was most pronounced on flagellomeres 10 to 35. Most of the reduction in sensilla on Lab. 1 males occurred in the scaled region (Table II). Lab 1 males had an average of 59% less s. trichodea in the scaled regions of flagellomeres 10 to 35 than either wild or Lab. 2 males. Moreover, there was no

TABLE I. Calculated total numbers of s. trichodea on both antennae of wild and laboratory-reared adults before (Lab. 1) and after (Lab. 2) the addition of wild insects to the laboratory colony.

Source	Mean $\pm$ standard error*	
	Males	Females
Wild	9,528 $\pm$ 98 a**	5,728 $\pm$ 109 c
Lab. 1	7,239 $\pm$ 127 b	4,643 $\pm$ 109 d
Lab. 2	9,095 $\pm$ 151 a	6,159 $\pm$ 93 c

*N = 5 for wild; 15 for Lab. 1; and 10 for Lab. 2.

**Different letters indicate differences at 1% level of probability according to Duncan's multiple range test.

TABLE II. Average numbers of *s. trichodea* on scale-free and scaled regions of flagellomeres 10-35 of males.

Source	Flagellar region	
	Scale-free	Scaled
Wild	57.7 $\pm$ 5.9* a**	54.6 $\pm$ 5.9 b
Lab. 1	51.9 $\pm$ 4.6 a	22.6 $\pm$ 3.7 c
Lab. 2	56.5 $\pm$ 5.1 a	51.7 $\pm$ 6.4 b

*Mean $\pm$ standard deviation (n = 8).

**Different letters indicate differences at 1% level of probability, only between insect sources, according to Duncan's multiple range test.

significant difference among the scale-free regions of males of the three strains, or in the scaled regions between wild and Lab. 2 males.

In a survey (Nagy 1981) of the sensilla and their distribution on the antennae of the Oriental fruit moth, only two (*s. trichodea* and *s. auricillica*) of the 15 types of sensilla increased in numbers with the addition of wild insects to the 20-year-old laboratory colony. Furthermore, only 2 chemo receptors exhibited sexual dimorphism: *s. trichodea* (more on males) and *s. auricillica* (more on females). As *s. auricillica* made up only 7.6% of the total sensilla on the antennae of males and their function is uncertain, they were not included in this study. *S. trichodea*, on the other hand, make up most of the total sensilla on the antennae of males, are 1.6 times more abundant in males than females, and respond to female-produced pheromone in other moths (O'Connell 1975; Albert *et al.* 1974; Schneider 1969).

If indeed *s. trichodea* are the pheromone receptors on males of *G. molesta*, then the reduced numbers found on the antennae of the Lab. 1 colony could be explained as the result of selection for fewer sensilla in the laboratory-reared colony or as a release from selection for many *s. trichodea* in the wild population. Virgin females are more widely dispersed in the wild than in laboratory colonies. Thus males with large numbers of *s. trichodea* might have an advantage under field conditions whereas in the laboratory the reverse might be true. This does not explain, however, why the *s. trichodea* in the scaled regions were reduced while those in the scale-free region remained the same in the laboratory population. Such a difference would be expected if the functions of the *s. trichodea* in each of the two regions were different. An examination of the ultrastructures of the sensilla in the scaled and scale-free areas is underway. We believe that the *s. trichodea* in the scaled region of *G. molesta* act as receptors of female-produced pheromone, whereas the *s. trichodea*, in the scale-free ventral longitudinal band, are responsible for the perception of a variety of odours emanating from substrata.

As the Lab. 1 colony of *G. molesta* no longer exists, it cannot be determined if the mating performance of males from that colony would be less competitive in the field than that of wild males. If mating performance in the field could be shown to be correlated with the numbers of *s. trichodea* in the scaled region of the antennae of male moths, then a means of measuring changes in a characteristic which affects field performance would be available for monitoring males in colonies reared for field release.

It is not known how many generations were required to reduce the numbers of sensilla by 59%, but it is known that augmentation of the laboratory colony

with wild insects restored the numbers of sensilla on laboratory-reared insects to the wild level over a five month period of three or four generations. Laboratory colonies of moths can now be compared with wild moths and wild insects added as required.

That a morphological change in the numbers of sensilla and their distribution patterns was detected in a laboratory colony, clearly indicates that caution must be exercised in assuming that morphological, and perhaps even physiological and behavioral characteristics, observed in laboratory-reared insects are always the same as those in the wild.

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PROTURA (ARTHROPODA: HEXAPODA) COLLECTED FROM SOUTHERN ONTARIO

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Abstract

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Proturans (Arthropoda: Hexapoda) have been reported only for the extreme northwestern part of Canada near Reindeer Stn., N.W. Territories. Soil cores taken from widespread areas of southern Ontario revealed the presence of proturans. Near Windsor, proturans were encountered at frequencies of 627/m² which means these arthropods are not as rare as entomologists believed. Statistical analysis of the frequency of occurrence of proturans in soil cores show that they are highly aggregated.

Introduction

Proturans are small (< 1.5 mm) hexapods lacking eyes and antennae and are associated with moist habitats where they feed on decomposing organic matter. They have piercing-sucking mouthparts, which are inserted deeply into the head capsule. The forelegs have assumed the function of the missing antennae and the second and third pairs of legs are used for walking. Proturans are most numerous in woodland humus with several hundred occupying one square metre, but they are also found in alpine meadows, animal nests, and tree cavities (Nosek 1973). Protura are distributed over most of the globe and the northernmost record is probably that from the Mackenzie Delta region of northern Canada (Tuxen 1955) rather than Iceland as stated by Nosek (1973). Tuxen (1955) reviewed a Canadian collection of over 100 specimens of Protura collected in 1948 by Dr. M. Hammer, and placed all, except one (which was *Eosentomon* sp., immature), in the genus *Acerentulus*. These specimens were the first and only record to date of Canadian Protura. In the course of extracting microarthropods from soil cores taken from different areas of southern Ontario over the past few years, we have found Protura in various habitats.

Materials and Methods

Soil cores, 5 cm dia $\times$ 15 cm deep, were collected from several sites and transported to London for extraction by modified Tullgren funnels as described by Tomlin (1978). Extracted arthropods were sorted using a dissecting microscope and taxa recorded. Proturans were either mounted separately on microscope slides using Heinze-PVA mounting medium or stored in a mixture of alcohol:water:glycerin (70:25:5).

A separate intensive survey of soil arthropods at Windsor Airport provided 492 soil cores from seven different dates during 1976 and 1977. These cores had their proturan content analysed to determine their dispersion which was measured by computing k of the negative binomial using the equation:

$$k = (\bar{X})^2 / (S^2 - \bar{X})$$

Results and Discussion

Photomicrographs of two specimens are shown in Figs. 1 & 2. The geographical location, habitat, date, and soil type are given in Table I. Protura were



Figs. 1 - 2. Protura (Arthropoda: Hexapoda) collected from southern Ontario: 1. Eosentomoidea, 70X; 2. Acerentomoidea, 70X.

found in 6 Ontario counties from Essex in the west to Frontenac in the east and Muskoka to the north. All specimens (except the two from Guelph found on 16 Aug. 1979, which belong to Superfamily Acerentomoidea), belonged to Superfamily Eosentomoidea. Among the arthropods extracted from soil cores, Protura were encountered least commonly, which could be a function of either the extraction technique or of their low frequency of occurrence in soil, or both. The sites listed represent areas which were sampled fairly intensively, suggesting that Protura are probably widespread throughout Ontario and Canada. If intensive sampling were carried out at any given site, the presence of Protura should eventually be established. Unlike the Hammer collection from northern Canada, which was dominated by specimens of Acerentomoidea, the present collection had all but 2 specimens from the Eosentomoidea.

The most proturans found in any one soil core was 20 from turf along the runways at Windsor Airport where they were particularly numerous. The mean frequency of occurrence of proturans in cores taken on seven sampling dates in 1976 and 1977 was 1.32 proturans/core ($672/\text{m}^2$), which is not very rare (Table II). Other sampling sites were not as productive. Not all specimens of Protura from Windsor were retained in our collection, because they were found so frequently.

The statistical analysis of the proturan content of the 492 cores taken at Windsor revealed that the variance was larger than the mean in all cases (Table

TABLE I. Location and habitat of Protura found in Ontario.

Geographical Location	County	Habitat	Date	No. specimens	Soil Type
Windsor	Essex	turf	15 Oct./75	4	clay loam
"	"	"	15 Apr./76	13	" "
"	"	"	1 July/76	1	" "
"	"	"	27 July/76	3	" "
"	"	"	28 July/76	3	" "
"	"	"	3 Aug./76	1	" "
Arnell Farm	Wellington	cornfield	6 July/78	1	sandy-clay loam
" "	"	"	16 Aug./79	2	" " "
Cloyne, 5 km. E.	Frontenac	mixed forest	17 Aug./77	4	organic litter
Bryanston	Middlesex	pasture	26 June/79	3	clay loam
Adelaide	"	orchard	4 Nov./77	1	sandy-clay loam
Keswick	York	drainage ditch	1 Sept./81	1	organic muck
Bradford	York	hedgerow	19 June/81	1	organic muck
Beausoleil Island	Muskoka	mixed forest	21 Aug./78	5	organic litter

II) suggesting that proturan populations are aggregated. In all cases the k of the negative binomial (or dispersion parameter) was less than 1, indicating a strongly clumped distribution (Southwood 1978). Results suggest that proturans are not as rare as expected from the dearth of specimens in general insect collections, and that woodland habitats are not the only place where proturans are in abundance.

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TABLE II. Mean, variance and k of the negative binomial (dispersion parameter) of Protura in the turf at Windsor, Ontario in 1976 and 1977.

Sampling Date	No. of Protura	No. Cores	Mean No./core $\bar{X}$	Variance S^2	k
15 Apr./76	69	60	1.15	3.8	0.50
23 June/76	55	72	0.76	1.5	0.75
3 Aug./76	43	72	0.60	1.4	0.40
25 Sept./76	116	72	1.61	5.5	0.66
10 May/77	119	72	1.65	10.3	0.31
19 Sept./77	168	72	2.33	13.5	0.48
20 Oct./77	79	72	1.10	2.5	0.88

**OBSERVATIONS ON OVERWINTERING OF THE FACE FLY,
MUSCA AUTUMNALIS
(DIPTERA: MUSCIDAE) NEAR GUELPH, ONTARIO**

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The occurrence of overwintering unmated face flies in frame houses, old buildings, attics and roofspaces of homes has been well documented (Graham-Smith 1918; Dobson and Matthew 1960; and Teskey 1969). In Indiana, Dobson and Matthew (1960) reported large numbers of flies seeking entrance under eaves and cracks on exterior walls of buildings. Face flies were active with cluster flies, *Pollenia rudis* (Fab.) (Calliphoridae) in attics of homes during the warm days of the spring and fall. Hammer (1942) presumed that face flies must overwinter in hollow trees and under bark but was unable to find them although Kearns (1942), did find flies in these sites. Teskey (1969) reported that face flies emerged from overwintering sites in Ontario in early April but that males were not observed on cattle until June. Diapausing face flies were reported in September in Ontario and fertile females were gradually replaced by unmated females between 15 September and 10 October. This new study was designed to observe the overwintering condition of face fly populations and determine the nature and location of overwintering sites in the Guelph area.

Face flies were collected from April through September 1974, and dissected to determine the state of fat body and egg development. During April 1974, face flies were captured in seven CO₂-baited cone traps. Five were located in pastures and 2 in wooded areas in the Guelph area of southern Ontario. Flies were collected twice a week from 12 April to 31 May and preserved in 70% alcohol: 5% glycerin for dissection.

Adult flies were collected from the faces of cattle using an insect net, and preserved for dissection. In addition, freshly dropped manure was marked twice weekly from 13 May to 16 September. From 5 to 10, 24-hour-old pats were collected from each pasture, placed in pans containing sand and returned to an open outdoor shelter for larval development. Pupae were sifted from the sand, counted and placed into cages for adult emergence. Adults were maintained for 3 weeks on 25% malt sugar solution³ and citrated beef blood⁴. Adults were then preserved until dissected.

A search for overwintering sites was made during the fall of 1973 and the spring and fall of 1974. Areas surveyed included numerous buildings, hollow trees, stumps, brush piles and ground hog (*Marmota monax*) burrows. Burrows were sampled by placing 30.5 x 20.6 cm. white plywood boards covered with "stickem" near the entrance. One hundred and eighty potential hibernating sites were also constructed. These consisted of wooden blocks with holes drilled in them, plastic straws imbedded in plaster of Paris or straws glued between cardboard sheets. These were placed near potential hibernation sites in the fall of 1973.

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³Type P.M. Regular Panamalt, Standard Brands Ltd., Montreal.

⁴Fresh, Collected from local abattoires as required, and citrated on site to prevent coagulation.

All natural and artificial sites were checked weekly until December and again in the spring for the presence of flies.

In 1974 the first face flies were observed on cattle and buildings on 20 April. From 21 to 29 April, females were caught on sticky boards and in CO₂ traps with an average of 120 females per trap on 29 April. Flies were not active at overwintering sites below 16°C. Once cattle were on pasture in mid May, face flies were not captured in the CO₂-baited traps.

The percentage of face flies having well developed fat bodies, indicative of diapause condition, from April through October 1974 is shown in Table I. Face flies from the campus pasture and Arkell pastures had similar patterns of fat body depletion and development. The presence of fat bodies in face flies decreased from 90% on 20 April to 0% by 30 May. This decline was accompanied by an increase in the number of mated females with ovarian development, as determined by dissection of spermatheca and ovaries. Fat body reserves were not observed in flies again until autumn. The percentage of flies with fat body increased from 18% on 21 August to 100% on 21 October. Flies captured at an overwintering site on 21 October, all had well developed fat bodies. The decrease in the amount of fat body in flies in the spring and increase of fat body in the fall was observed in flies captured during photoperiods of 15 hrs. 5 min. and 15 hrs. 11 min. respectively (including civil twilight). These photoperiods corresponded to those used in earlier laboratory experiments (Caldwell and Wright 1978).

Flies overwintered in 3 buildings near the research sites. On 21 April 1974 several thousand overwintering flies were active in and around a grey wooden garage at the Arkell Research Station. Approximately 500 flies, mostly males, were resting on sunny sides of the garage. Inside the garage, flies were attracted to daylight at two windows. Within one week the majority of flies had mated, and females dispersed to outlying areas. Males did not follow and presumably died near the overwintering site. There was no activity of flies at this site again until 21 October when several hundred flies were seen on and in the garage. Dissection of these flies indicated that all had extensive development of fat body. Face fly males and females were also seen clustered on sunny areas of two garages near a University of Guelph pasture. The following spring, emerging adults were observed at both sites in late April. Sites were similar to those reported by Benson and Wingo 1962, and Teskey 1969.

Natural overwintering sites probably exist although in this study none was found. Flies were not found in the artificial sites provided. Some male and female face flies were captured on sticky boards associated with groundhog holes in April. This suggested overwintering sites other than buildings.

TABLE I. Number and Percentage of field-collected female face flies with fat body and/or egg development during 1974 near Guelph, Ontario

Date	Arkell Pasture				Campus Pasture			
	Total dissected	Fat bodies		Egg development	Total dissected	Fat bodies		Egg development
		No.	%			No.	%	
April 21	257	230	89	0	0	—	—	—
22	16	2	13	10	0	—	—	—
26	12	3	25	8	0	—	—	—
27	22	8	37	19	0	—	—	—
28	117	65	56	111	50	24	48	96
May 1-16	Cold, wet—No flies active	—	—	—	—	—	—	—
17	27	10	37	25	—	—	—	—
21	25	4	16	24	50	—	—	—
28	—	—	—	—	25	1	2	100
June 1-Aug 19	1,467	0	0	1,467	1,354	3	12	25
Aug. 21	44	8	18	36	0	0	0	100
28	48	8	17	40	50	9	18	82
30	29	10	35	19	50	18	36	64
Sept. 16	35	20	57	15	0	—	—	—
Oct. 28	50	50	100	0	23	13	56	44
					0	—	—	—

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(Received 11 December 1981)

**SUPPRESSION OF THE FUNGI *ZOOPHTHORA*
SPP. BY CAPTAFOL: A TECHNIQUE TO STUDY INTERACTION
BETWEEN DISEASE AND PARASITISM IN THE ALFALFA WEEVIL
HYPERA POSTICA (COLEOPTERA: CURCULIONIDAE)**

CONRAD LOAN

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Natural epizootics of the larval disease caused by 2 species of *Zoophthora* (= *Entomophthora*) fungi (Harcourt *et al.* 1981) have been mainly responsible for the population decline of the alfalfa weevil *Hypera postica* (Gyllenhal), that began in southern Ontario during the mid seventies (Harcourt *et al.* 1977). Since 1979, populations have been further constrained by *Microctonus aethiopoides* Loan and *M. colesi* Drea, 2 species of wasps that attack those individuals that survive the disease. Whereas *M. aethiopoides* attacks the adult stage, thereby avoiding direct competition with the fungi, *M. colesi* attacks the larval stage and must compete directly for the same hosts. This has fostered concern as to the ultimate persistence of *M. colesi* in southern Ontario.

To gain information on the compatibility of *M. colesi* and the fungi, a field technique was developed using the fungicide captafol (Difolatan 4.8 F) to protect the alfalfa weevil from disease.

The work was carried out in May and June, 1981 in fields of commercial alfalfa at 2 sites near Moira in the Bay of Quinte area. Site 1 contained a 4-ha stand of 2-year-old Thor alfalfa, and site 2, a 10-ha stand of 4-year-old Northrup-King blend. Within each field, a study area measuring 15 × 30 m was subdivided into 8 plots of equal size, 7.5 × 7.5 m, and arranged in a paired design of 4 replicates. Captafol was applied at the rate of 2.1 Kg AI/ha using a portable compressed air sprayer. Six applications were made between 21 May and 9 June. The incidence of disease was determined on 9 and 11 June by counting the number of dead weevil larvae on the apical 10 cm of 50 alfalfa stems taken at random from each plot. Numbers of adult weevils emerging in sprayed and unsprayed plots were compared in 1-m² samples of alfalfa harvested on 24 June and held in outdoor cages. Rates of parasitism were determined from weevil larvae collected on 19 June, and from adults emerging from the samples of alfalfa.

The foliar applications of captafol inhibited development of the fungi at both sites, reducing the incidence of larval disease by 88 to 99% (Table I). Numbers of emerging adults were correspondingly increased.

TABLE I. Numbers of larvae of *H. postica* killed by the fungi *Zoophthora* spp., and of adults emerging from cocoons in study plots at Moira, Ontario, 1981

Site	Date	Dead Larvae			Emerging Adults		
		Not Treated	Captafol Treated	% Reduction	Not Treated	Captafol Treated	% Increase
1	9 June	549	41	92.5	—	—	—
	11 June	416	51	87.8	—	—	—
	24 June	—	—	—	7	978	99.3
2	9 June	107	5	95.4	—	—	—
	11 June	104	1	99.0	—	—	—
	24 June	—	—	—	49	1056	95.4

In the treated plots, 77% of the weevil larvae were parasitized by *M. colesi*. The ratio of parasite eggs to larvae was 2:1. Superparasitism was common, the number of supernumeraries per host ranging from 1 to 11 with a mean of 4.2. In the untreated plots, only 13% of the adults were parasitized and none was superparasitized.

These results suggest, but do not prove, that the parasites were attracted to the higher host densities in the treated plots. Because the egg stage of *M. colesi* was more abundant than the larval stage, the data further imply that peak attack occurred after the disease epizootic had begun to subside.

It is concluded that captafol is a promising research technique for biological studies on *M. colesi* where disease epizootics caused by *Zoophthora* spp. occur.

Acknowledgments

I thank N. Bostanian of the Agriculture Canada Research Station, St. Jean-sur-Richelieu, for advice and samples of captafol, G. Wylie of the Agriculture Canada Research Station, Winnipeg, for reviewing the manuscript, and my colleagues for their comments on the research and manuscript.

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(Received 13 January 1982)

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THE SOCIETY

IN MEMORIAM

J. Ronald Gates (1924-1982) passed away suddenly on 17 October 1982. Ron Gates graduated in entomology from the University of Guelph in 1950. He worked for about two years at the Chatham Entomology Laboratory and then dedicated 32 years of service to Libby, McNeill and Libby in Chatham. He was assigned to, and eventually was in charge of the Pest Management Section of Libby's Agricultural Service. Ron was well liked and will be missed by his friends and associates.

Ron is survived by his wife, Winnifred, and two daughters, Nancy and Carol.

PRESIDENT'S PRIZE — 1982

This year the Entomological Society of Ontario met jointly with the Entomological Societies of Canada and America at Toronto, Ontario. For this occasion, students from the 3 Societies competed for a President's Prize in each of 8 categories. The winner in each category was selected by a panel of 3 judges, one representing each society. Each winner received a certificate and \$100.00. Congratulations go to the winners listed by category below:

Systematics, Morphology and Evolution Gary Gibson, University of Alberta
Use of thoracic muscles as a character system for phylogenetic analysis of Hymenoptera.

Physiology, Biochemistry & Toxicology R.L. Glaser, Cornell University
Vitellogenin uptake by isolated ovaries of *Aedes aegypti*.

Biological Control Jane Wright, University of California, Berkeley.
Host discrimination and competition by *Encyrtus saliens*, an imported scale parasite in California.

Ecology Vytautas Bindokas, University of Illinois, Chicago
Effects of electric fields on honey bees.

Bionomics and Insect-Plant Relationships Chantal Briand, Universite Laval
Performance of cereal aphids *Rhopalosiphum padi* and *Sitobion avenae* on three wheat varieties.

Behavior Elaine Backus, University of California, Davis
The internal sensory systems and feeding behavior of a leafhopper, *Graphocephala atropunctata* Signoret.

Medical and Veterinary Entomology Erik Runstrom, Purdue University
Distribution and dispersion of German cockroaches in urban apartments.

Crop Protection Entomology Thomas Perring, University of Nebraska
The Banks grass mite in the corn canopy microenvironment.

INSECT CONTROL ON POTATOES IN ONTARIO FROM 1973 TO 1982

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Abstract

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Field tests conducted from 1973 to 1982 indicated that in Ontario effective control of the potato leafhopper, the potato flea beetle, the tarnished plant bug and Colorado potato beetle was obtained with such insecticides as acephate, azinphosmethyl, carbofuran, methamidophos and methidathion and the synthetic pyrethroids, cypermethrin, fenvalerate and permethrin. When azinphosmethyl, chlorpyrifos, methidathion, cypermethrin or permethrin were applied, large populations of the green peach aphid developed. This did not occur with acephate, methamidophos or fenvalerate or if an effective aphicide such as pirimicarb or ethiofencarb was included in the treatment.

Introduction

Economic insect pests of potatoes in Ontario include the potato flea beetle, *Epitrix cucumeris* (Harris); potato leafhopper, *Empoasca fabae* (Harris); tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois); Colorado potato beetle, *Leptinotarsa decemlineata* (Say); and four aphid species, the green peach aphid, *Myzus persicae* (Sulzer); the potato aphid, *Macrosiphum euphorbiae* (Thomas); the buckthorn aphid, *Aphis nasturtii* Kaltentbach; and the foxglove aphid, *Acyrtosiphon solani* (Kaltentbach). Most of these insects can be controlled by insecticides applied as foliar sprays. Azinphosmethyl, carbaryl, carbofuran, endosulfan, methamidophos, methidathion and phosmet are recommended in Ontario. Some of these (carbofuran, methamidophos) control aphids, but often additional insecticides such as mevinphos, oxydemeton-methyl, and pirimicarb may be needed for aphid control.

Resistance to some chlorinated hydrocarbon, carbamate and organophosphate insecticides has developed in insect pests on potatoes (Harris and Svec 1976, 1981; Chapman and Bauernfeind 1976; Devonshire *et al.* 1977). In addition, aphid populations may increase following application of some insecticides. Cancelado *et al.* (1979) reported an aphid problem after the application of azinphosmethyl while Root and Gowan (1978) found that carbaryl induced a population outbreak of aphids on potatoes, whereas carbofuran did not. In Ontario, tests have been conducted since 1973 to assess insect control in potatoes and develop effective control programs. These tests are summarized here.

Method

From 1973 to 1982, experimental potato plots were established at Cambridge, Ontario, on sandy loam soil. The variety Kennebec was used in all tests and plots consisted of 4 rows, 15 m long. Plots were separated laterally with 2 rows of corn to reduce pesticide drift between plots. The treatments were applied with a low-volume, tractor-mounted sprayer delivering either 750 L/ha (1973-76) or 800 L/ha (1977-82). The boom was equipped with one overhead nozzle and two drop nozzles per row. Weekly applications were made during July and August, except in 1973 when insecticides were applied every second week. Each treatment was replicated 4 times.

Two methods were used to evaluate the efficacy of the pesticides. Sweep net sampling for potato flea beetle, potato leafhopper, tarnished plant bug and Colorado potato beetle was done 2 days after each spray application. This sampling involved 8,

180° sweeps of a 38-cm net on the 2 centre rows of each plot with one step taken between sweeps. To assess aphid populations, aphids were counted on 4 randomly selected haulms in each plot. From 1973 to 1977, all aphids from the 4 haulms of each plot were removed and preserved in alcohol for identification to species. Generally, green peach aphid was the only species of aphid present except in the check plots. Therefore, from 1978 to 1982, aphids were collected only from the check plots and from those treated plots where field inspection indicated species other than the green peach aphid were present. The preserved samples were used to verify species counts. Data were analyzed by least significant difference of means by ANOVA or Duncan's multiple range test (Steel and Torrie 1960; Sokal and Rohlf 1973).

At the end of the season (late September), the two centre rows of each plot were harvested and yields determined.

Results

Populations of the potato flea beetle (Table I) varied greatly among years. In all years (Table II, III) effective control was obtained with acephate, carbofuran, methamidophos, cypermethrin, deltamethrin, permethrin and fenvalerate. With higher populations in 1974 and 1978, some insects survived in plots treated with chlorpyrifos, methamidophos, profenofos and thiofanox. Oxamyl did not provide satisfactory control. In 1977, thiofanox provided good control on either a 7-day schedule at 0.25 kg a.i./ha or a 14-day schedule at 0.5 kg a.i./ha. In 1978, under high population pressure on a 14-day schedule, methidathion was less effective than carbofuran.

Excellent control of the potato leafhopper (Table II, III) was provided by cypermethrin, deltamethrin, fenvalerate and permethrin. Chlorpyrifos, methamidophos, profenofos, thiofanox and the lowest rate of oxamyl were less effective than the other treatments. On a 14-day schedule, all treatments reduced the population but none provided outstanding control. Thiofanox provided good control either on a 7-day schedule or 14-day schedule at the highest dosages. On a 14-day schedule, methidathion and carbofuran were not effective.

TABLE I. Mean numbers of potato insects in unsprayed potato plots at the Cambridge Research Station, Ontario, 1973-1982.

Species	Sampling Method	Mean number ¹									
		1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Potato flea beetle	8 sweeps	127	424	39	82	33	446	5	36	96	77
Potato leaf-hopper	8 sweeps	21	94	20	21	90	59	3	20	97	39
Tarnished plant bug	8 sweeps	10	18	25	21	73	29	21	35	27	86
Colorado potato beetle	8 sweeps	— ²	—	—	—	—	—	6	41	41	31
Aphids	4-haulm count	27	19	10	67	4	14	20	167	20	80

¹Mean of 3 dates; mean number per 8 sweeps or per 4 haulms

²Insufficient insects present to evaluate control.

TABLE II. Mean potato insect control 2 days after each treatment of Kennebec potatoes with various insecticides on a 7-day schedule, 1974-1982.

Insecticide	Rate ¹ (kg a.i./ha)	Insect control				
		² PFB	PLH	TPB	CPB	A
Acephate	0.55 — 1.10	³ 6/6	5/6	7/7	0/2	7/7
Azinphosmethyl + ethiofencarb	0.50 — 0.66 +0.25 — 0.275	4/4	2/4	4/4		1/4
Carbofuran	0.275 — 0.55	5/5	5/5	6/6		0/6
Chlorpyrifos	0.5	4/4	2/4	4/4	2/2	0/4
Cypermethrin	0.05 — 0.15	5/5	5/5	6/6	2/2	0/6
Deltamethrin	0.005 — 0.04	3/3	3/3	3/3	3/3	0/3
Ethiofencarb	0.275 — 1.1	0/2	0/2	1/2		1/2
Fenvalerate	0.05 — 0.15	5/5	5/5	6/6	2/2	3/6
Methamidophos	0.5 — 1.1	8/8	7/8	9/9	3/3	9/9
Methidathion	0.25 — 0.55	4/4	3/4	5/5		0/5
Oxamyl	0.5 — 1.92	4/5	3/5	5/5	2/2	2/5
Permethrin	0.015 — 0.14	8/8	8/8	9/9	3/3	0/9
Pirimicarb + carbaryl	0.068 — 0.275 +1.0 — 1.43	4/4	4/4	4/4		1/4
Profenofos	0.5 — 1.0	2/2	0/2	2/3		2/3
Thiofanox	0.14 — 0.50	3/3	2/3	3/3		0/3

¹Rates generally varied between years of the experiment; lowest and highest rates are shown.

²PFB-potato flea beetle; PLH-potato leafhopper; TPB-tarnished plant bug; CPB-Colorado potato beetle; A-aphids.

³No. of years with > 90% control/no. years tested.

The tarnished plant bug (Table II, III) was controlled satisfactorily by all insecticides. Excellent control was obtained with carbofuran, oxamyl, cypermethrin, fenvalerate and permethrin.

After developing in late July, aphid populations reached maximum numbers in late August. Table II and III summarize data obtained during the last week of August for each of the years 1973 to 1982. These data show that excellent control was obtained with acephate, ethiofencarb, methamidophos, oxamyl or profenofos. By contrast, populations of the green peach aphid following treatment with carbofuran, chlorpyrifos, deltamethrin, methidathion, cypermethrin and permethrin developed much higher than in non-sprayed control plots. At low dosages, fenvalerate apparently stimulated aphid populations while at higher dosages populations were suppressed.

Data from 1978 (Table IV) illustrate the extent of aphid build-up and control on a seasonal basis following various insecticide treatments.

Colorado potato beetles were present in sufficient numbers to evaluate control only in 1980, 1981 and 1982 (Table I). All treatments were effective except acephate (Table II, III).

TABLE III. Mean potato insect control 2 days after each treatment of Kennebec potatoes with various insecticides on a 14-day schedule, 1973, 1977-79.

Insecticide	Rate (kg a.i./ha)	Insect control				
		¹ PFB	PLH	TPB	CPB	A
Carbofuran	0.50 — 0.55	² 2/2	1/2	1/2	— ³	0/2
Ethiofencarb	1.1	0/1	0/1	0/1	—	0/1
Methamidophos	1.1	1/1	0/1	0/1	—	0/1
Methidathion	0.25 — 0.50	0/1	0/1	0/1	—	0/2
Pirimicarb + carbaryl	0.275 +1.43	1/1	0/1	0/1	—	0/1
Thiofanox	0.825	1/1	1/1	1/1	—	0/1

¹PFB-potato flea beetle; PLH-potato leafhopper; TPB-tarnished plant bug; CPB-Colorado potato beetle; A-aphids.

²No. of years with > 90% control/no. years tested.

³Insufficient insects present to evaluate control.

Yields were taken each year. However, only in 1981 were yields in treated plots significantly different from those in non-treated control plots. Differences in 1981 probably resulted from severe damage by the Colorado potato beetle in untreated plots that year.

Discussion

The potato leafhopper and potato flea beetle were controlled effectively with any of several insecticides and there was no evidence that during the period 1973 to 1982, any of these species developed resistance. Good control was consistently obtained with foliar sprays of acephate, carbofuran, azinphosmethyl, carbaryl, methamidophos, methidathion, cypermethrin, fenvalerate and permethrin. Although each of these insecticides effectively controlled tarnished plant bug, the economic importance of this insect on potatoes is questionable. When present in large numbers on potatoes, these insects cause blossom drop which growers like to prevent. However, protecting the blossoms may have more aesthetic than economic value. Dr. W.A. Rawlins (pers. comm.) of Cornell Univ., Ithaca, NY., found that removal of blossoms prior to fertilization prevented seed ball formation and sometimes increased tuber yield.

In Ontario, 4 species of aphids can be found on potatoes but, the green peach aphid, the major vector of potato leafroll and potato mosaic viruses A and Y, is the most important. A number of workers (e.g. Root and Gowan 1978) have reported a build-up of aphid populations after application of certain insecticides, including carbaryl, to potatoes. Our tests document that build-up occurred with azinphosmethyl and a number of other insecticides including 2 of the synthetic pyrethroids, cypermethrin and permethrin. By contrast, another synthetic pyrethroid, fenvalerate, when used at 0.15 kg a.i./ha, was an effective aphicide against the green peach aphid.

The reason why aphid populations increased after application of certain insecticides has not been established. One suggestion is that the insecticides kill important predators. Something else must have been involved, however, since in our tests, only the green peach aphid populations increased, while populations of other species (noted in the check) did not. F. Ferguson, and R.K. Chapman (pers. comm.) of the Univ. of Wisconsin,

TABLE IV. Mean number of aphids¹ per 4 haulms 2 days after each treatment of Kennebec potatoes with various insecticides on 7- and 14-day schedules, 1978.²

Treatment	Formulation	Rate (kg a.i./ha)	Mean ³ no. aphids					
			27/7 ⁴	3/8	10/8	17/8	24/8	31/8
Acephate	75WP	0.75	2 bc	0 a	1 a	0 a	1 a	0 a
Carbofuran ⁵	4F	0.5	0 a	1 a	2 a	4 a	124 ab	25 ab
Carbofuran	4F	0.5	0 a	1 a	2 a	4 a	10 a	24 ab
Chlorpyrifos	4C	0.5	0 a	2 a	2 a	61 cde	407 d	899 d
Cypermethrin (Ripcord®)	40EC	0.05	3 c	3 a	5 a	73 de	315 cd	575 c
Cypermethrin (Ripcord®)	40EC	0.075	3 c	13 bc	6 a	161 f	392 d	1096 d
Fenvalerate	30EC	0.05	0 a	3 a	1 a	5 a	25 a	130 ab
Fenvalerate	30EC	0.075	2 bc	2 a	1 a	2 a	57 a	76 ab
Fenvalerate	30EC	0.15	0 a	1 a	1 a	1 a	7 a	7 a
Methamidophos	4WM	0.5	0 a	1 a	3 a	0 a	0 a	0 a
Methidathion ⁵	25EC	0.25	2 bc	10 b	16 b	69 de	381 d	181 ab
Methidathion ⁵	25EC	0.5	3 c	0 a	5 a	40 abcd	129 ab	254 b
Methidathion	25EC	0.25	1 ab	0 a	2 a	87 c	206 bc	528 c
Permethrin (Ambush®)	500EC	0.08	1 ab	1 a	5 a	52 bcde	134 ab	120 ab
Profenofos	720EC	0.5	2 a	2 a	3 a	1 a	4 a	2 a
Profenofos	720EC	1.0	1 ab	1 a	2 a	0 a	0 a	1 a
Thiofanox	2EC	0.14	1 a	1 a	2 a	3 a	37 a	73 ab
Thiofanox	2EC	0.28	0 a	1 a	3 a	14 ab	4 a	4 a
Check			7 d	16 a	26 c	24 abc	3 a	1 a

¹The species was *Myzus persicae* except in control plots where 3 species were present; *Macrosiphum euphorbiae* (57%), *Aphis nasturtii* (26%) and *Myzus persicae* (17%).

²Treated 4, 11, 18, 25 July; 1, 8, 15, 22, 29 August; and 5 September.

³Means followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

⁴Date sampled.

⁵Applied on a 14-day schedule, 4, 18 July; 1, 15, 29 August.

Madison, WI., found that with carbaryl, populations of the green peach aphid increased much more rapidly in treated plots than in untreated plots despite the exclusion of parasites and predators from both treatments.

The tests reported here indicate that the insecticides acephate, carbofuran, fenvalerate (except at 0.05 kg a.i./ha for the green peach aphid), and methamidophos were most effective in Ontario for controlling the potato insect complex including the green peach aphid. If azinphosmethyl or carbaryl were used, aphid control would require the addition of an aphicide such as pirimicarb or ethiofencarb.

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EVALUATION OF INSECTICIDAL BAITS FOR CONTROL OF THE CABBAGE MAGGOT, *DELIA* (= *HYLEMYA*) *BRASSICAE* (DIPTERA: ANTHOMYIIDAE), ON RUTABAGAS

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Abstract

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Adult cabbage maggots, *Delia* (= *Hylemya*) *brassicae* (Wied.), preferred sucrose and yeast hydrolysate in laboratory tests of 6 baits. With the addition of either parathion, dimethoate, diazinon or permethrin to sucrose, the mixtures were progressively less attractive. The addition of either sucrose, yeast hydrolysate or skim milk powder to a parathion spray mixture, and of sucrose to a dimethoate spray mixture had no significant effect, compared to insecticides alone, on mortality of adults caged on treated rutabaga leaves in the field. Mortality was significant compared to unsprayed checks for up to 6 days with 0.50 kg a.i./ha dimethoate, and for up to 4 days with 0.25 kg a.i./ha parathion. Parathion, applied as a foliar spray to rutabagas at 0.25 kg a.i./ha, reduced the number of flies caught on sticky traps by $> 50\%$ for 2 to 3 days, and dimethoate, at 0.50 kg a.i./ha, for 7 days. Five kg/ha of sucrose added to parathion or to dimethoate sprays had no significant effect on mortality.

Introduction

The cabbage maggot, *Delia* (= *Hylemya*) *brassicae* (Wied.), is an important pest of cruciferous crops throughout the temperate zones of the Holarctic region. In Ontario, it attacks rutabagas rendering them useless for storage and shipment. Carbofuran, chlorfenvinphos, and fensulfothion are moderately persistent soil insecticides registered for use in Ontario at planting and at regular intervals throughout the season. Recent experimental evidence suggests that the efficacy of these insecticides has declined (Sears and McGraw 1981). Only chlorfenvinphos has provided adequate control of larvae in efficacy experiments during 1977-1981 at the University of Guelph. Resistance of larvae to organophosphorous and carbamate insecticides is suspected.

An alternative to treating soil for the control of larvae is to direct insecticides against adults by treating foliage. At present, only parathion is recommended for control of adults on rutabagas (Anon. 1982). To provide better control, greater residual toxicity is desirable. For several species of flies, baits have been added to insecticides to increase mortality at the time of treatment or to increase residual toxicity (Steiner 1952; Barnes and Ortega 1959). The objective of this study was to examine the effectiveness of insecticidal baits for the control of cabbage maggot flies attacking rutabagas.

Materials and Methods

Six different baits were tested in the laboratory for relative attractiveness to flies. This was done by counting the number of flies resting or feeding on paper strips which had been dipped in aqueous solutions of the baits. The solutions were: 20% sucrose, 20% molasses, 20% honey, 10% yeast hydrolysate, 10% soy hydrolysate and 10% casein hydrolysate. Flies were reared in the laboratory and the adults were provided with a mixture of honey and yeast hydrolysate until 2 to 4 days old. Then they were starved for 24 h with access only to water. Males and females were separated and 300 of one sex were placed in each of 2 screened cages (30 x 30 x 30 cm) where they were allowed 1 h to adjust to test conditions ($27 \pm 1^\circ\text{C}$, RH $30 \pm 5\%$). At the start of each experiment, 6 strips (3 x 20 cm) of green blotting paper, each of which had been dipped in a different bait solution, were hung in a row from the front of the cage. A single 100-watt incandescent light bulb

was placed 50 cm from the front of the cage to attract flies to the vicinity of the strips. Flies resting or feeding (proboscis extended) were counted on both sides of the strips after 5, 7.5, and 10 min. For both males and females, each test was replicated 6 times using new groups of flies and new strips. Because more flies were attracted to the outer strips than the inner strips, the relative positions of the strips changed with each replication. Thus each treatment appeared once in each of the 6 locations.

The insecticides, diazinon, dimethoate, parathion, and permethrin, were mixed with sucrose and tested for relative attractiveness using the method as described earlier. Each insecticide was tested in a separate cage using 5 strips (4 x 20 cm) dipped in one of the following solutions: 20% sucrose, 20% sucrose + 0.025% insecticide, 20% sucrose + 0.125% insecticide, 0.025% insecticide, or a distilled water check. Permethrin was used at half these rates. Tests with each insecticide were replicated 5 times for each sex, with 250 flies per replicate.

Mortality of flies caged on rutabaga leaves which had been treated with insecticides and insecticidal baits was evaluated. Plants were treated in the field using a back-pack sprayer powered by compressed air. Each treatment was replicated 4 times with treatments arranged in a completely randomized block design. After the spray had dried, 10 flies from a laboratory colony were placed in a cylindrical cage fastened around one treated rutabaga leaf in each replicate. Mortality was recorded after 24 h. The leaf was removed from the plant to prevent its reuse, and new flies were caged daily on other leaves until mortality on treated leaves approximated that of the untreated checks.

The effectiveness of insecticides alone and insecticidal baits in reducing the number of flies in small fields of rutabagas was evaluated at the Elora Research Station, University of Guelph. Plots were 0.13 ha and separated by at least 500 m by non-cruciferous crops. At the start of the experiment, 30 yellow sticky boards were placed in each plot and examined daily at dusk from 16 August to 14 September. On 20 August, 2 plots were treated with parathion at 0.25 kg a.i./ha, 2 were treated with parathion at 0.25 a.i./ha + sucrose at 5.0 kg/ha, and 2 served as untreated checks. The same treatments were applied to the plots on 28 August. On 5 September, the 2 plots previously treated with parathion alone were treated with dimethoate at 0.50 kg a.i./ha. The second pair, previously treated with parathion + sucrose, were treated with dimethoate at 0.50 kg a.i./ha + sucrose at 5.0 kg/ha and the remaining 2 served as untreated checks. Fields were sprayed between 0800 and 0930 h using a 4-row, tractor-mounted sprayer with overhead nozzles.

Results and Discussion

Females fed most actively on yeast hydrolysate (29 flies), sucrose (26 flies) and honey (20 flies) (Fig. 1). Compared to these 3 baits, molasses, casein hydrolysate and soy hydrolysate were less attractive ($P < 0.05$). Males fed most actively on sucrose (15 flies) and honey (15 flies) which were more attractive than the other 4 materials tested. In comparing the feeding responses of the sexes, more females than males fed on all baits with the exception of honey. Of the flies resting on the strips, the majority were also feeding. On yeast hydrolysate, 90% of the females were feeding, followed by 89% on sucrose and 82% on honey. This compares with 69% of the males feeding on yeast hydrolysate, 81% on sucrose and 82% on honey.

Niemczyk (1965) recorded similar results in tests with the onion maggot fly, *D. antiqua* (Meigen). He found that yeast hydrolysate was more attractive to females than to males, and that honey was equally attractive to both sexes. The two most attractive materials to cabbage maggot flies in the present study were sucrose and yeast hydrolysate. Because sucrose was the least expensive of the two, and is easily soluble, it was studied further to evaluate its attractiveness when mixed with insecticides.

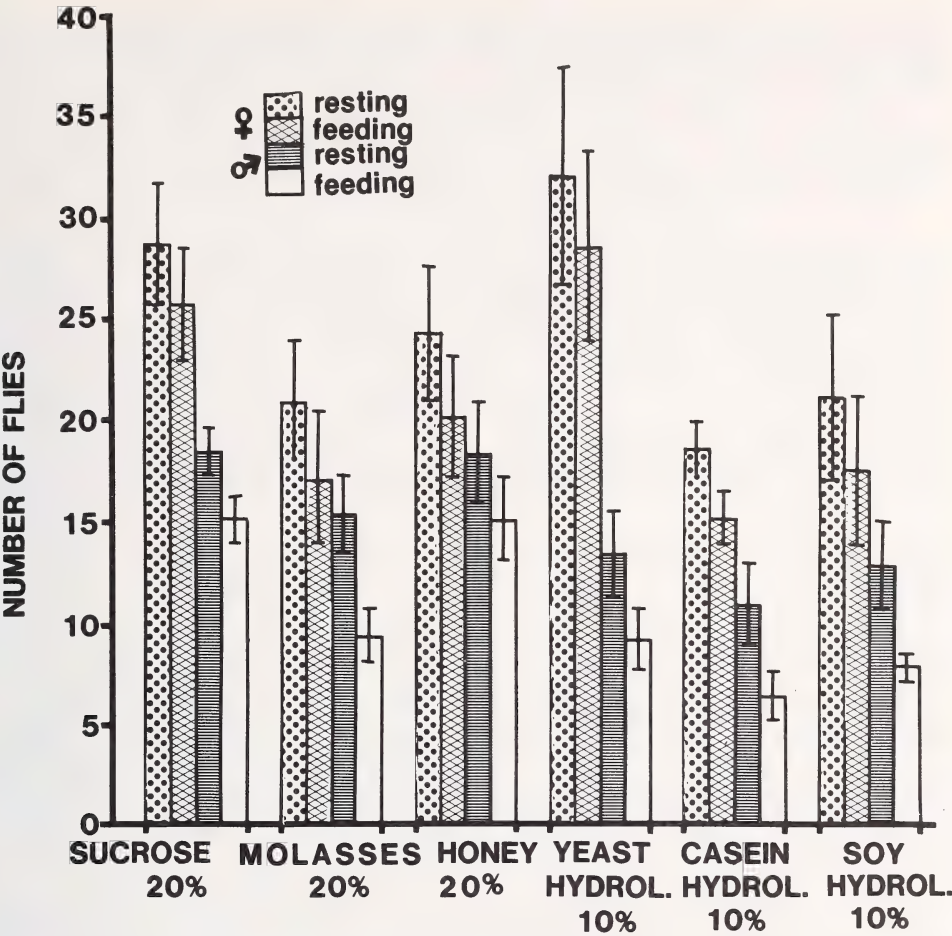


FIG. 1. Number of female and male *Delia brassicae* resting and feeding on strips treated with each of 6 baits.

Parathion and dimethoate caused the least disruption to flies feeding on strips treated with various combinations of sucrose and insecticides (Table I). In tests with parathion, a mean number of 21.5 females fed on sucrose, which was not different from the mean numbers which fed on sucrose mixed with either 0.025% (18.1) or 0.125% (12.3) parathion. By comparison, a mean of 2.5 fed on parathion alone, and 6.2 fed on distilled water. The mean number that fed on sucrose (27.0) was not different from 18.9, the number that fed on sucrose mixed with 0.025% dimethoate. In tests using both permethrin and diazinon there was less feeding on strips treated with the insecticides mixed with sucrose than on strips with insecticides alone. The response of males was similar to that of females. The feeding response of both sexes to insecticides mixed with sucrose was, in decreasing order of preference: parathion, dimethoate, permethrin, and diazinon. Parathion or dimethoate combined with sucrose were most suited to further bioassay tests under field conditions.

TABLE I. Number of *Delia brassicae* feeding on strips of blotting paper dipped in solutions of various combinations of sucrose and insecticides.

Treatment	Number Feeding (Mean + S.E.) ^a			
	Parathion	Dimethoate	Permethrin ^b	Diazinon
Female				
20% sucrose check	21.5+5.2gh	27.0+5.4h	14.9+2.6gh	22.1+4.8gh
20% sucrose + 0.025% insecticide	18.1+3.0gh	18.9+5.4gh	4.2+0.5cde	3.7+0.9bcd
20% sucrose + 0.125% insecticide	12.3+2.2fg	15.2+4.2fg	3.7+1.0bcd	3.3+0.7bcd
0.025% insecticide	2.5+0.6abc	1.9+0.8ab	1.2+0.3a	4.3+0.5cde
distilled water check	6.2+1.5de	5.9+0.9de	4.1+0.9cde	7.7+1.4ef
Male				
20% sucrose check	9.4+3.0de	7.9+0.5de	7.2+1.7de	11.9+3.4e
20% sucrose + 0.025% insecticide	10.9+4.9de	7.1+2.2de	2.5+0.7abc	1.6+0.8a
20% sucrose + 0.125% insecticide	9.2+3.4de	3.9+0.9bcd	0.8+0.3a	0.9+0.3a
0.025% insecticide	2.9+1.2abc	1.4+0.5a	1.6+0.6ab	1.4+0.3ab
distilled water check	3.9+0.7bcd	4.2+0.7cd	2.5+0.6abc	2.8+1.2abc

^a Means in both columns and rows followed by the same letter are not significantly different at $P < 0.05$ (Duncan's Multiple Range Test). Data transformed by $\log(x+1)$ before analysis.

^b Permethrin at half the treatment rates of other insecticides.

TABLE II. Per cent corrected mortality (one day posttreatment) and the number of days of significant mortality of *Delia brassicae* adults caged for 24 h on rutabaga leaves treated with insecticides.

Insecticide (kg a.i./ha)	Bioassay					
	12 September		29 September		11 October	
	Mortality (%) ^a	(days) ^b	Mortality (%) ^a	(days) ^b	Mortality (%) ^a	(days) ^b
parathion (0.25)	94a	4	86a	1	0a	0
dimethoate (0.50)	90a	4	100a	4	4ab	0
diazinon (0.25)	84a	4	97a	2	0a	0
permethrin (0.13)	84a	2	35b	0	57b	1
naled (0.25)	90a	1	93a	1	0a	0

^a Means in columns followed by the same letter are not significantly different ($P < 0.05$), Duncan's Multiple Range Test.

^b Number of days for which mortality on treated leaves differed from that on untreated leaves ($P < 0.05$).

In a series of bioassay tests, various insecticides were compared for mortality to flies caged on treated leaves on plants in the field (Table II). In the first two bioassays, mortality was significant ($P < 0.05$) for 1 to 4 days with parathion, dimethoate, and diazinon and for 1 to 2 days with permethrin and naled. In the bioassay begun on 11 October, only permethrin caused significant mortality. During this period, the weather was cold, with up to 5 mm of rain recorded each day. These conditions could influence toxicity. The efficacy of permethrin could be explained because pyrethroids have a negative temperature coefficient of toxicity (Harris and Kinoshita 1977).

Of the insecticides compared in these tests, dimethoate was the most persistent, followed by parathion and diazinon. The variable and sometimes brief persistence of permethrin was not expected. Leeper and Reissig (1980) found that permethrin had an LT_{50} of 13 days to caged adult pear psylla, and Bailie and Morgan (1980) claimed that it provided satisfactory control of flies on cattle for one week. Pree (1979), however, found that *Macrocentrus ancylovorus* Rohwer, a hymenopterous parasite of the oriental fruit moth, was killed only on the day of application.

Mortality of flies on leaves treated with parathion increased with increasing rates of parathion (Table III). Mortality varied from 0 to 72% at the low rate (0.125 kg a.i./ha) to

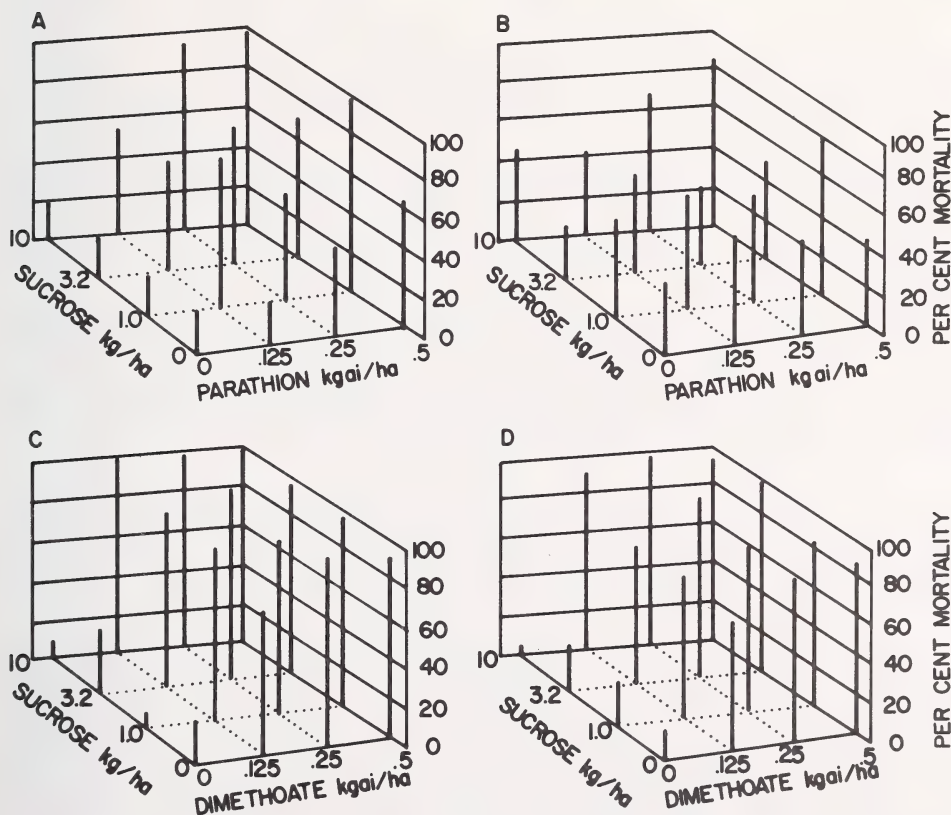


FIG. 2. Per cent mortality of *Delia brassicae* caged for 24 h on rutabaga leaves with a mixture of sucrose and parathion on 22 Aug. 1979 (A and B) or sucrose and dimethoate on 25 Sept. 1979 (C and D); A and C, 1 day posttreatment; B and D, 2 days posttreatment.

TABLE III. Per cent corrected mortality (one day posttreatment) and the number of days of significant mortality of *Delia brassicae* caged for 24 h on rutabaga leaves treated with various rates of parathion or dimethoate.

Insecticide (kg a.i./ha)	Bioassay					
	22 August (parathion)		29 September (parathion)		25 September (dimethoate)	
	Mortality (%) ^a	(days) ^b	Mortality (%) ^a	(days) ^b	Mortality (%) ^a	(days) ^b
0.125	0a	0	72a	1	68a	6
0.25	29ab	0	86a	1	97a	6
0.50	52b	1	100a	2	90a	6

^a Means in columns followed by the same letter are not significantly different ($P < 0.05$), Duncan's Multiple Range Test.

^b Number of days for which mortality on treated leaves differed from that on untreated leaves ($P < 0.05$).

52 to 100% at the highest rate (0.50 kg a.i./ha). During the bioassay begun on 22 August, considerable rainfall was recorded (38 mm) which reduced the efficacy of parathion during that period. Significant mortality was recorded for all rates of dimethoate up to 6 days following treatment.

Mortality of flies recorded one day after leaves were treated with 16 combinations of parathion and sucrose, was greatest when the highest concentrations of each ingredient was used (Fig. 2a). The addition of sucrose increased mortality, but not significantly. By the second day, only the highest rates of parathion with sucrose caused significant mortality (Fig. 2b).

When mortality was evaluated on leaves treated with combinations of dimethoate and sucrose, the addition of sucrose did not increase mortality significantly on either day one or two (Fig. 2c). Mortality on the second day was slightly reduced (Fig. 2d). In this experiment, mortality continued to decline from the fourth to sixth day, and by the eighth day, it was no longer significant. Apparently dimethoate was sufficiently toxic that the addition of sucrose did not increase mortality.

Mortality on leaves treated with parathion alone ranged from 72% with 0.125 to 100% with 0.50 kg a.i./ha parathion one day following application (Table IV). The addition of sucrose, yeast hydrolysate or skim milk powder (a source of casein) did not enhance mortality which varied from 45 to 97%. There was also little difference in the number of days of significant mortality which ranged between 1 and 2 days.

Applications of parathion and parathion combined with sucrose were applied to small field plots on 20 August. After treatment, the number of flies caught in fields 1 and 2 (parathion alone) dropped for 2 days before increasing on the third day (Fig. 3). At the same time, the number of flies caught in fields 3 and 4 (parathion + sucrose) declined more substantially, and did not recover until 4 days after treatment. When the number of flies caught in the 3 days preceding treatment was compared with that caught in the same period after treatment, a greater reduction occurred in the fields which were treated with the parathion and sucrose mixture than in the fields treated with parathion alone (Table V).

The same treatments were applied again on 28 August (Table V). The number of

TABLE IV. Per cent mortality (one day posttreatment) and the number of days of significant mortality of *Delia brassicae* caged for 24 h on rutabaga leaves treated with mixtures of baits and parathion on 29 Sept., 1979.

Treatment		Parathion (kg a.i./ha)	Mortality	
Bait	Rate (kg/ha)		(a) ^a	(days) ^b
sucrose	1.0	0.125	72 bcd	1
sucrose	1.0	0.50	97 de	1
sucrose	10.0	0.125	45ab	1
sucrose	10.0	0.50	83 de	1
yeast hydrolysate	1.0	0.125	76 bcde	1
yeast hydrolysate	1.0	0.50	79 cde	2
yeast hydrolysate	10.0	0.125	83 bcde	1
yeast hydrolysate	10.0	0.50	97 de	1
skim milk	1.0	0.125	52 bc	1
skim milk	1.0	0.50	93 de	1
skim milk	10.0	0.125	79 bcde	1
skim milk	10.0	0.50	97 de	1
no bait		0.125	72 bcde	1
no bait		0.50	100 e	2
no bait		0.00	0	

^a Means in columns followed by the same letter are not significantly different ($P < 0.05$), Duncan's Multiple Range Test.

^b Number of days for which mortality on treated leaves differed from that on untreated leaves ($P < 0.05$).

TABLE V. Number of *Delia brassicae* per sticky board per day for 3 days before and 3 days following treatment, and the per cent change in number following treatment of field plots at Elora, Ontario, 1979.

	Treatment		
	Insecticide alone	Bait + Insecticide	Untreated
20 August:			
Parathion 0.25 kg a.i./ha			
Sucrose 5.0 kg/ha			
No. flies pre	1.44	1.60	2.67
No. of flies post	1.19	0.38	4.20
% change	-17	-76	+57
28 August:			
Parathion 0.25 kg a.i./ha			
Sucrose 5.0 kg/ha			
No. flies pre	4.08	3.76	5.97
No. of flies post	1.20	1.00	5.56
% change	-71	-73	-7
5 September:			
Dimethoate 0.50 kg a.i./ha			
Sucrose 5.0 kg/ha			
No. flies pre	2.26	2.76	2.71
No. of flies post	0.34	0.41	3.32
% change	-85	-85	+23

flies trapped in fields 1 and 2 (parathion alone) was reduced for 3 days, and did not increase until 4 days after treatment, and the number trapped in fields 3 and 4 (parathion + sucrose) declined for 4 days before a noticeable increase occurred. Both treatments reduced the numbers of flies after treatment to the same extent, whereas the number of flies captured in the untreated fields remained relatively unchanged.

A final treatment was applied on 5 September (Table V). The number of flies trapped in fields treated with dimethoate alone and dimethoate mixed with sucrose dropped for 7 days and did not increase until the eighth day after treatment. In the treated fields the per cent reduction in fly numbers was identical.

Based on these experiments, the addition of sucrose to parathion may extend mortality of flies in the field by one day. Simply increasing the rate of application as shown in the bioassay experiments (Table III), would have the same effect. These results were disappointing when compared with those of some other studies with insecticidal baits. Steiner (1952) found that protein hydrolysates and sugar added to parathion provided effective control of fruit flies for 2 to 3 weeks in Hawaii. In Florida, the Mediterranean fruit fly was eradicated in 1956-57 with a spray of protein hydrolysate and malathion (Steiner *et al.* 1961). Barnes and Ortega (1959) extended the control of the walnut husk fly in California from 7 days to 12 days with malathion and protein hydrolysate. Other authors, however, have found that the addition of baits to insecticides made no difference because the insecticides already were effective (Ba-Angood 1977; Reissig 1977).

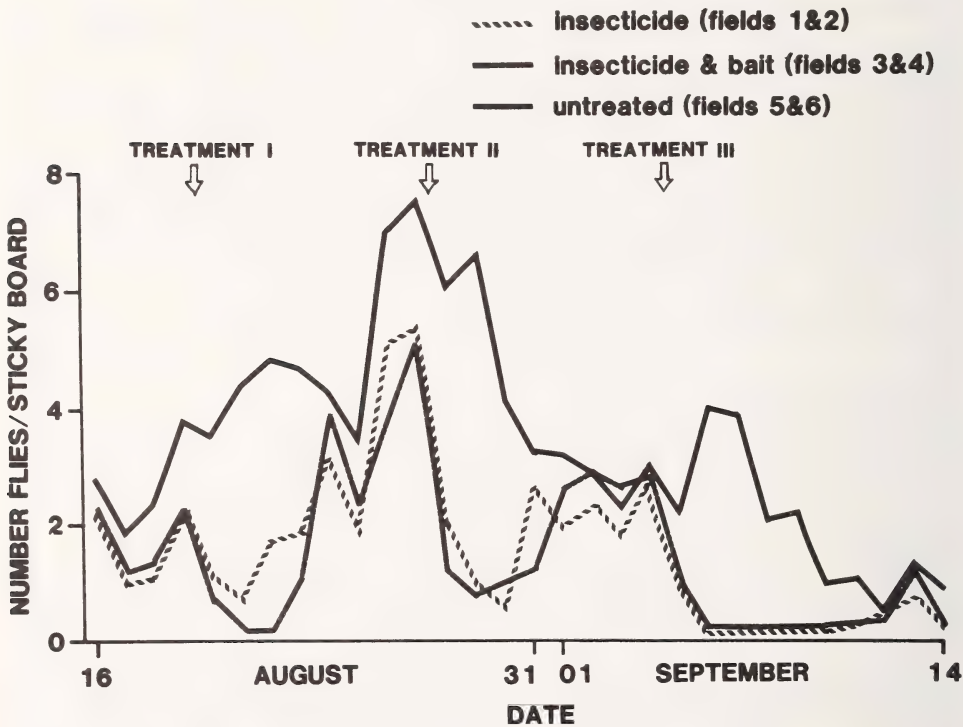


FIG. 3. Number of *Delia brassicae* adults captured per sticky board trap in plots of rutabagas treated with parathion or dimethoate and insecticide-bait mixtures at Elora, Ontario, 1979. (Each line is the average of 2 fields).

The addition of sucrose to dimethoate did not affect mortality of flies in the field, which lasted 7 days with or without sucrose. This was consistent with the results in bioassay experiments (Fig. 2), in which sucrose added to dimethoate had no effect. It appeared that dimethoate was sufficiently toxic on its own that the addition of sucrose could not increase its effectiveness. The effectiveness of dimethoate indicated that its registration for control of aphids on rutabagas in Ontario could be extended to cabbage maggot flies.

Because foliar sprays are capable of reducing a population of flies for only a short period of time, with or without the addition of baits, the cost of control based solely on repeated applications would be prohibitive. However, if the cabbage maggot developed full resistance to the persistent granular or drench treatments presently used in Ontario, growers may be forced to treat for adults. Parathion or dimethoate used as a foliar spray when a threshold number of flies is exceeded, could provide a useful alternative to the present method of control.

Acknowledgement

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**INJURY TO GRAIN CORN BY THE FALL ARMYWORM,
SPODOPTERA FRUGIPERDA
(LEPIDOPTERA: NOCTUIDAE), IN SOUTHWESTERN ONTARIO, 1977 TO 1981**

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Abstract

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Infestations of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), in grain corn fields caused yield reductions up to 200 kg/ha in 1977 when ears were lost due to shank injury. Further damage resulted from larval feeding on the kernels and from mold which developed on damaged kernels near the tips of ears. Smaller losses occurred from 1978 to 1980 and there was no observable damage in 1981.

Introduction

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith), overwinters in the United States, but is restricted to regions where sustained or intermittent development is possible, e.g. southern Florida and southern Texas (Wood *et al.* 1979). Migrant moths do not reach Ontario until late summer.

In 1977, severe outbreaks were reported over a wide area of the United States and southern Ontario. Host plants in the U.S.A. included peanuts, soybeans, cotton, grain sorghum, corn, pasture grasses, and commercial hybrid grasses on golf courses, lawns, cemeteries and football fields. Damage to crops in Alabama was the most serious ever observed (Bass 1978) and it was so difficult to control on vegetables in Pennsylvania that growers gave up (Tetrault 1978). Forage crop losses alone in Georgia were estimated at \$137.5 million (Sparks 1979). In southern Ontario, cover crops were destroyed and late sweet corn was heavily infested (Kelleher 1977).

The observations reported here were obtained in conjunction with a study of the European corn borer, *Ostrinia nubilalis* (Hübner), from 1977 to 1981. The aim of the study was to determine the extent of damage by the fall armyworm to grain corn in southwestern Ontario.

Materials and Methods

A single-cross corn hybrid, WF9 x M14, susceptible to both generations of the European corn borer, was used throughout the study in plots on Brookston clay soil at Woodslee and sandy loam soil at Harrow, Ontario. The experimental procedures were similar each year at Woodslee. Plots were hand-seeded with 2 seeds/hill on two dates, usually 10 to 12 May and again 10 to 12 days later. If both seeds germinated, the plots were thinned to 1 plant/hill. Half of each planting was harvested between late September and mid October and half in late October to early November. This provided 4 combinations of planting and harvest dates: early planting and harvest (EE); early planting, late harvest (EL); late planting, early harvest (LE); late planting and harvest (LL). Within each of these combinations there were four 9-row plots with approximately 40 plants/row. Each plot had: 1, a row of plants treated for control of 1st-generation corn borer; 2, a row treated for control of the 2nd generation; 3, a row treated for control of both generations; 4, an untreated check row. There was an untreated guard row on each side of a treatment row. Each planting and harvest combination was replicated 4 times with treatment rows arranged in a Latin square design. Carbaryl (1.68 kg a.i./ha) was applied at weekly intervals to control the corn borer.

Experimental procedures at Harrow varied between years. In 1977 and 1978, they were the same as for Woodslee. In 1979, all plots were planted the same day but there was an early and late harvest. One-third of the plots were untreated, one-third were treated for 1st-generation corn borer, and one-third for 2nd-generation borer. No plots were treated for both generations. In 1980 and 1981, procedures were similar to 1979, except there were no control plots for treatment of 1st-generation borers.

Plants were examined during the late summer and fall to determine how many ears were on the ground due to feeding in shanks by the corn borer and fall armyworm. Shank damage by the armyworm usually consisted of short cavities (ca. 1 to 1.5 cm) whereas corn borers often made long cavities. In some instances, when ears dropped due to armyworm feeding, the shanks were cut nearly straight across. Often larvae were still present in the shank when dropped ears were examined. When larvae were absent and there was doubt as to which species caused damage, the ears were not counted. At harvest, plants were split from tassel to ground level to determine stalk infestations. Ears were examined for damage and the numbers of chewed kernels recorded. Larvae from damaged ears were identified, the number of ears with fall armyworm recorded, and the percent infestation calculated. This percent infestation was used to estimate numbers of damaged ears due to fall armyworm when larvae were not present for identification. Ears were not counted as damaged if only one kernel was chewed or there was boring in the tip of the cob but no kernel damage.

Commercial corn fields were examined in 1977, 1980 and 1981 for ear losses due to fall armyworm, but no records were made of kernel damage.

Results

In 1977, ears were lost in all plots regardless of planting and harvest dates or location (Table I). Losses were greater at Woodslee on the clay soil than at Harrow on the sandy loam soil and were greater in late-planted than early-planted corn at both sites, even though there was only a 10-day difference in planting dates.

At harvest, many ears had kernel damage from feeding by the fall armyworm (Table I). In one plot, all the damaged ears had fall armyworm *in situ*, and in several others 75-80% of the damaged ears contained larvae. Although, on average, only 14.7 to 27.3 kernels were damaged per ear, some individual ears were severely damaged. Percentage ear damage was higher in the late plantings at Harrow, but similar for both plantings at Woodslee. There were as many as 6 larvae/ear *in situ* at both sites so damage would have been more severe if infestations had started earlier and/or the harvest had occurred later.

There was no apparent relationship between earlier insecticide treatments for control of European corn borer and either the number of ears damaged or the average damage per ear.

Twenty-nine commercial fields were examined for ear loss due to fall armyworm from 1 October to 15 November 1977. For the two-week periods 1 to 15 October, 16 to 31 October, and 1 to 15 November, the average numbers of ears on the ground per hectare were 28.6, 142.9 and 642.9, respectively. A field examined on 15 November had 1000 ears/ha on the ground due to shank damage by the fall armyworm and 375 ears/ha down because of shank and stalk injury by the European corn borer. These data illustrate the importance of harvesting as early as feasible if ear loss due to insect damage is to be kept to a minimum.

Infestations in 1978 were much lighter throughout southern Ontario and those areas of the United States where severe infestations were reported in 1977. Although the

TABLE I. Ear loss and kernel damage caused by the fall armyworm to grain corn in Ontario

Year	Location	Planting and harvest treatment ^a	Ear loss due to shank boring		No. ears estimated to be damaged		
			No. plants examined	% ear loss	No. ears examined	% ears with kernel damage	Average no. kernels chewed/damaged ear
1977	Harrow	EE	564	0.35	323	38.08	18.3
		EL	569	0.35	287	41.81	14.7
		LE	553	0.72	316	71.20	27.3
		LL	556	1.26	425	67.76	26.3
	Woodslee	EE	548	0.73	213	52.58	14.9
		EL	552	0.72	— ^b	—	—
		LE	561	1.60	320	58.13	25.4
		LL	553	1.99	— ^b	—	—
1978	Harrow	EE	283	0.35	143	12.59	22.9
		EL	258	0.39	144	19.44	26.1
		LE	265	0.75	138	20.29	24.0
		LL	276	1.45	142	35.21	32.1
	Woodslee	EE	528	0.19	426	13.62	24.8
		EL	476	0.84	— ^b	—	—
		LE	522	0.19	419	9.31	21.1
		LL	500	0.00	— ^b	—	—

^a EE, early-planted and harvested; EL, early-planted, late-harvested; LE, late-planted, early-harvested; LL, late-planted and harvested.

^b No ears examined.

percentages of ears on the ground from shank damage were similar in the 2 years at Harrow, fewer ears were lost in 1978 at Woodslee (Table I).

The percentages of ears with damaged kernels were much lower in 1978, particularly at Woodslee (Table I). The maximum numbers of larvae *in situ* per ear at Harrow and Woodslee were 2 and 3, respectively. More ears were damaged in the late planting at Harrow, but the levels were similar for the 2 plantings at Woodslee. As in 1977, there was no relationship between earlier insecticide treatments and either the number of ears damaged or the average damage per ear.

In 1979, there was another major decrease in infestations. No ears were lost at Harrow or in any treatments except the late-planted and late-harvested plots at Woodslee where there was a 0.56% ear loss. The maximum percentage of damaged ears in any treatment at either site was only 8.50 and none had more than one larva *in situ*.

In 1980, there was no evidence of damage at Harrow, but damage at Woodslee was slightly higher than in 1979. Ear losses at Woodslee in EE, EL, LE and LL plots were 0.37, 0.36, 0.00 and 0.20%, respectively. The percentages of ears with kernel damage were 4.54 and 24.60 in the EE and LE plots, respectively, and the average numbers of kernels chewed per damaged ear were 18.0 and 17.6, respectively. A survey of 0.004 ha in each of 26 corn fields found only one ear on the ground due to shank damage by the fall armyworm. In 1981, there was no evidence of damage either in plots at Harrow and Woodslee or in 13 corn fields examined.

Discussion

Burkhardt (1952) noted that most workers observed fall armyworm larvae feeding on the leaves and in the ears of corn, but few were found in shanks and even fewer in stalks. He found considerable tunnelling in shanks in 1951 and in one field approximately 3% of the stalks had cavities. Our results agree with those of most investigators in that there was very little stalk damage. The difference between the observations of Burkhardt and those of others, including our own, could be related to corn maturity. Only 50% of the corn had tasseled when Burkhardt made his observations on 3 October 1951. However, Morrill and Green (1973) reported no damage to stalks even when the corn was immature.

Although late-planted sweet corn was seriously damaged by fall armyworm in 1977, the combined losses of grain corn due to fallen ears and chewed kernels were only moderate. The greatest number of fallen ears occurred in a commercial field where 1000 ears/ha were lost. Assuming an ear weight of 200 g, the yield reduction from fallen ears was 200 kg/ha. The greatest yield reduction in experimental plots was 116 kg/ha in the 1977 late-planted and late-harvested plots at Woodslee. However, there was a greater potential for damage since a yield loss of 523 kg/ha from fallen ears occurred in one plot. In addition, further losses occurred in many fields from mold which developed around damaged kernels at the tip portion of ears.

Severe outbreaks of the fall armyworm have occurred every 5 to 7 years in the central and eastern United States (Wood *et al.* 1979). Notes on insect infestations in Canada up to 1967 were published annually in the Canadian Insect Pest Review and after that date in the Canadian Agricultural Insect Pest Review. Moderate to severe outbreaks of this insect occurred in 1960 (MacNay 1960), 1964 (MacNay 1964), 1969 (Creelman 1969) and 1977 (Kelleher 1977) in southern Ontario. These reports, when combined with our data, show that the fall armyworm only caused concern one year between 1970 and 1981 and is therefore only of sporadic importance in this area.

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EVIDENCE FOR DISPERSAL OF DIAMONDBACK MOTH, *PLUTELLA XYLOSTELLA* (LEPIDOPTERA: PLUTELLIDAE), INTO SOUTHERN ONTARIO

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Abstract

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No stage of the diamondback moth, *Plutella xylostella* (L.), survived winter conditions in the field or simulated winter conditions in the laboratory. Captures of moths in pheromone traps in the spring correlated well with periods of southerly airflow directed over Ontario. Populations of moths occurring in commercial fields of Brussels sprouts during the latter part of the growing season were directly related to trap captures during the preceding spring. These relationships could be useful for predicting outbreaks of this pest.

Introduction

The diamondback moth, *Plutella xylostella* (L.), is an occasional pest of cruciferous crops in Ontario and can be a serious problem in some years. It does not diapause and continuous development occurs in sub-tropical areas of the world (Harcourt and Cass 1966). Frost (1949) reported that it overwintered as an adult or as a pupa in areas with temperate climates. The pupal stage was shown to be incapable of surviving winters in Ontario (Harcourt 1957, Butts and McEwen 1981) or in northern areas of Russia (Razumov 1970). In the Gor'kiy region of Russia (Razumov 1970) and at Ithaca, New York (Harcourt 1954) adults survived the winter in crop debris. Harcourt (1957) concluded that it did not overwinter in any stage at Ottawa, Ontario and postulated that moths overwintered in more southerly regions and dispersed north in the spring. Putnam (1978) presumed that the source of this species in western Canada is through dispersal from the south.

Long range dispersal of *P. xylostella* has been documented in Europe. The moth was considered to be a migrant to Great Britain from the continent and that dispersing swarms were responsible for heavy infestations along the east coast of Britain (Hardy 1938). The direction of dispersal was always related to wind patterns and involved distances of up to 3,200 km (French 1967). After an invasion of moths into Great Britain it was demonstrated that air flow patterns originating over Finland at an altitude of 1500 meters (Shaw and Hurst 1967) had directed the moths to the islands. Conclusive evidence of long-range dispersal was provided when thousands of moths descended on a weather ship 805 km WNW of Scotland (French and White 1960). Prevailing winds indicated that a flight of at least 1,600 km from the coast of Norway had taken place. In a similar incident, large numbers of moths were observed on Svalbard (Spitsbergen) in the Arctic ocean following a severe SSE storm. Moths had arrived in Finland the previous day and apparently had been carried across 1,000 km of sea to reach the islands in 24 hours (Lokki *et al.* 1978). The objective of our study was to evaluate the potential of *P. xylostella* to overwinter in southern Ontario and to examine the possibility of its dispersal from the south.

Materials and Methods

The cold hardiness of each life stage was assessed to determine the stage most likely to overwinter. Approximately 1,000 larvae and pupae were held at $12^{\circ}\text{C} \pm 1^{\circ}\text{C}$ for 3 weeks and for an additional 6 months at $4 \pm 2^{\circ}\text{C}$. Relative humidity was maintained at

$60 \pm 10\%$ and a 8h:16h SD photoperiod was provided. Survival was recorded periodically. Another 500 pupae and 500 eggs, held at $8^{\circ}\text{C} \pm 1^{\circ}\text{C}$ with a 10 h photophase, were inspected weekly for development.

Survival of *P. xylostella* during the winter was assessed in a small field plot near Cambridge (Hespeler), Ontario containing 4 cabbage and 4 Brussels sprouts plants and many seedlings of yellow rocket, *Barbarea vulgaris* R.Br. enclosed in a large nylon screen cage (3x2x2 m). Between the end of September and the end of October, 1980, approximately 5,000 individuals were introduced into the cage. These included 2,300 pupae, 1,200 adults, 500 larvae and 1,000 eggs. Adults were marked with fluorescent powder for identification. Adults that emerged from pupae placed in the cage were marked as they emerged through a mixture of vermiculite and fluorescent powder. Some pupae were placed in wire-mesh bags to protect them from predation by mice. Eggs, on paper towelling, were placed in screened plastic containers for protection. Larvae were transferred onto cabbage and Brussels sprouts plants in the cage. Activity in the cage was observed during the fall and samples were periodically examined during the winter to determine survival. The cage was removed after the first snowfall in December and replaced in March. A pheromone-baited trap was placed in the cage on 28 March and inspected twice each week until 4 June.

Pheromone-baited traps (Chisholm *et al.* 1979) were placed at several locations in southern Ontario during this study. Traps were located at the University of Guelph Horticulture Research Station, Cambridge, Ontario in 1979 and 1980 in areas where plots of cruciferous crops were grown annually. In 1981, traps were placed at two additional locations; one near Millgrove, Ontario where cruciferous crops were grown commercially and cruciferous weeds were abundant in surrounding cultivated fields, and the other near Elora, Ontario in an area free of cruciferous crops, but where cruciferous weeds, especially yellow rocket, were present. All traps were inspected twice each week and the pheromone capsules in the traps were changed periodically. Yellow rocket plants and other cruciferous weeds growing near Millgrove and Elora were inspected for eggs and larvae during the spring. Temperatures were recorded at each location and degree-days above 7°C (Butts and McEwen 1981) were calculated.

Results and Discussion

All stages of *P. xylostella* survived for 7 weeks in the laboratory at 4°C but after 8 weeks eggs were no longer viable and few larvae were alive. Butts (1979) found that eggs were not viable after 6 weeks at 2°C . Pupae were alive after 8 weeks but the adults emerging from these were melanistic and had malformed wings. Several adults were alive after 11 weeks, but there was no survival after 3 months. No adults emerged from pupae maintained at 4°C for 6 months. Insects surviving the winter in southern Ontario would be periodically exposed to temperatures below 0°C for a period of 4 to 5 months. Butts (1979) found that 10 of 160 pupae held at 2°C for 6 months were viable and concluded that this insect could survive the winter as pupae. Pupae and eggs maintained at 8°C with a 10 h photophase continued to develop. Eggs hatched and pupae enclosed after a period of 6 to 8 weeks.

One of approximately 2,500 adults survived the winter during 1980-81 in the field plot near Cambridge, Ontario. Adults, larvae and pupae were active in the field cage until 20 November when the last inspection was made before snow covered the area. Samples of 200 pupae and 100 eggs were brought into the laboratory on 20 February, 23 March and 2 April and exposed to a 16 h photophase and to temperatures fluctuating from 19 to 25°C . Some pupae, and all of the eggs, appeared viable when they were brought to the laboratory, but after 2 weeks, no development was observed.

No males were captured in the pheromone-baited trap in the field cage. One surviving female was found inside the cage on 4 May. It was marked with orange fluorescent powder indicating that it had emerged the previous fall from a pupa placed in the field cage. Because the majority of those introduced into the cage did not survive, it was concluded that Cambridge, Ontario was near the northern limit for the winter survival of this moth. Butts (1979) reported that none of the 150 pupae and 100 adults that he exposed to winter conditions at Cambridge, Ontario, survived.

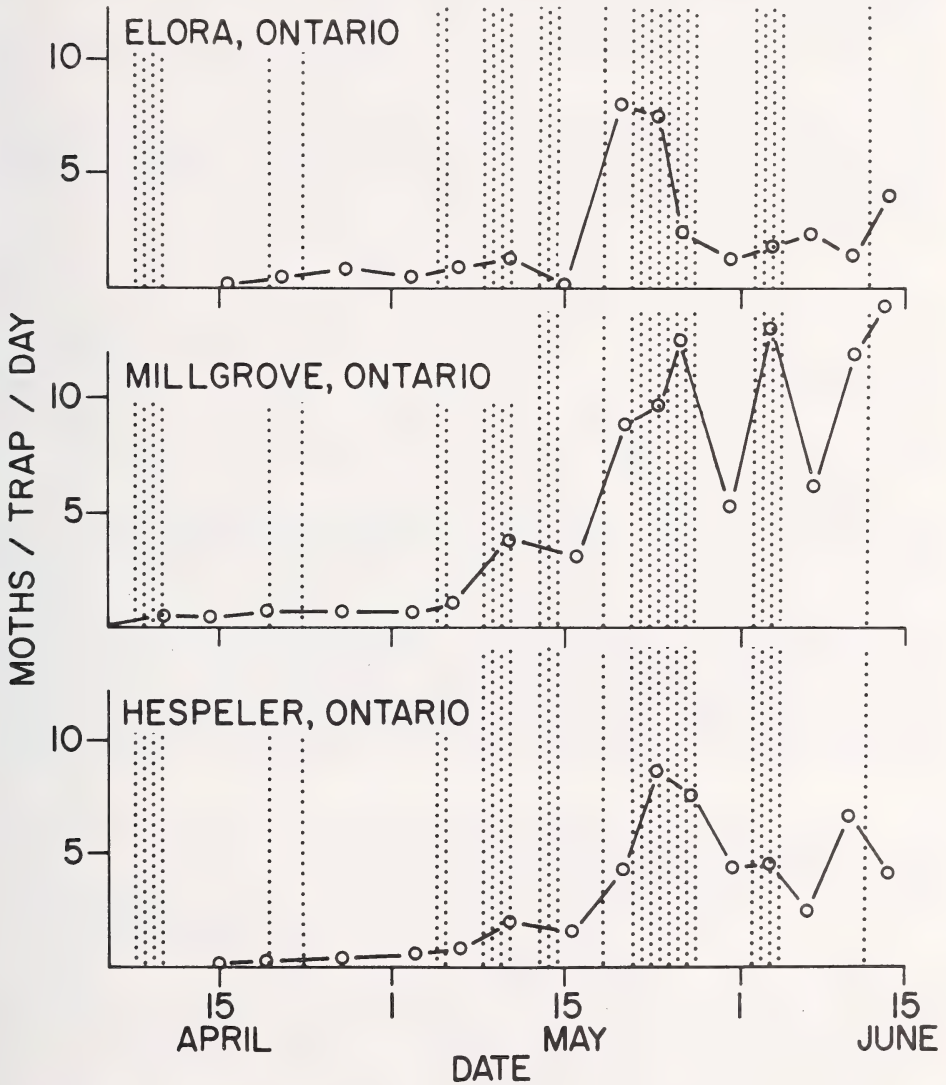


FIG. 1. Number of male *P. xylostella* captured in pheromone-baited traps during the spring of 1981. (Days of southerly air flow are indicated by shaded areas).

Pheromone-baited traps were placed in the field on 28 May 1979 and the first moth was captured the following day. At that time, 236 degree-days had accumulated above a threshold of 7° C. In 1980, the first traps were placed on 16 May and the first moths were captured on 19 May after 120 degree-days had accumulated. In 1981, the first traps were placed on 2 April in a variety of habitats. The first moths were captured during the second week of April after 40 degree-days had accumulated. Previously, the earliest record of adults captured in Ontario was 23 May near Ottawa, Ontario (Harcourt 1957). Butts and McEwen (1981) reported that in both 1977 and 1978 moths were present at Cambridge (on the basis of eggs found) shortly after sufficient degree-days (above 7° C) had accumulated to complete one generation (i.e. 300).

Leaves of yellow rocket were inspected for eggs beginning in early April. Four viable eggs were found on one plant collected near Elora, Ontario on 22 April. The first adults were captured in a trap at that location a few days earlier. Harcourt (1957) observed eggs of *P. xylostella* on yellow rocket on the same date that the first moths were detected near Ottawa. Yellow rocket grows in large clumps which remain green throughout the winter. Moths were attracted to this plant exclusively during April before other weeds and cruciferous crops became available.

Fluctuations in the population of adults during the spring of 1981 were very similar for all trap locations (Fig. 1) although the locations were 24 to 64 km apart and represented very different habitats. The number of moths captured during this period was also fairly consistent regardless of habitat. By late June however, the number of moths captured in crop areas far exceeded that of any other habitat. If large numbers of moths were able to survive the winter in Ontario, one would expect them to be initially captured on dates consistent with their phenological development and in areas where cruciferous crops were being grown each year. These events did not occur and it was concluded that moths were dispersing into Ontario each spring from the south.

Weather patterns which result in southerly air flow into Ontario commonly consist of a high pressure cell on the Atlantic coast resulting in a movement of air from the southern States northward along the Ohio River Valley to Ontario. Moths from the Gulf coast entering this air flow pattern could be carried to Ontario in less than 30 hours at average wind speeds of 60 km per hour. The number of days of southerly air flow in May was directly related to the number of moths caught per trap in May and to those of the subsequent generation trapped in June of 1979, 1980 and 1981 (Table 1). Traps were not maintained throughout May 1979 but the number of days of southerly air flow during this month was correlated with numbers of moths subsequently caught during June. In May 1980, few days of southerly air flow occurred and few moths were captured. During

TABLE I. Days of southerly air flow in May and number of male *P. xylostella* captured in pheromone traps during May and June of 1979-1981.

Year	Days of Southerly Air Flow in May	Moths Captured/Trap/Day	
		May	June
1979	9	*	3.7
1980	2	0.4	0.9
1981	18	8.1	7.9

*Traps were not in place for the entire month.

May 1981 there were 18 days of southerly air flow and the numbers of moths caught in May and June were much greater than in previous years. Moths were caught simultaneously at 3 different locations in southern Ontario on days of southerly air flow (Fig. 1).

The winter crop of cabbage is harvested from March until May in the southern United States. Peak numbers of *P. xylostella* occur there from the end of April until the first part of May (Reid and Bare 1952) and provide a reservoir of dispersing moths that could be carried north with favorable winds. A similar situation has been documented for the potato leafhopper, *Empoasca fabae* (Harris), which also builds up to large populations in the Gulf states during March and April (Medler 1957). Surveys have suggested a wave-like spread of this insect in a concentric pattern from the Gulf of Mexico northward. These periods of dispersal occurred on specific dates and were associated with southerly winds.

The number of moths captured during the spring appeared to be directly related to subsequent population densities later in the season. Low numbers of moths were captured in traps near Cambridge and Millgrove during the latter portion of the season in 1980 (peaks < 8 moths/trap/day) following a spring in which few moths were captured (Fig. 2), whereas greater numbers of moths were captured (peaks > 40

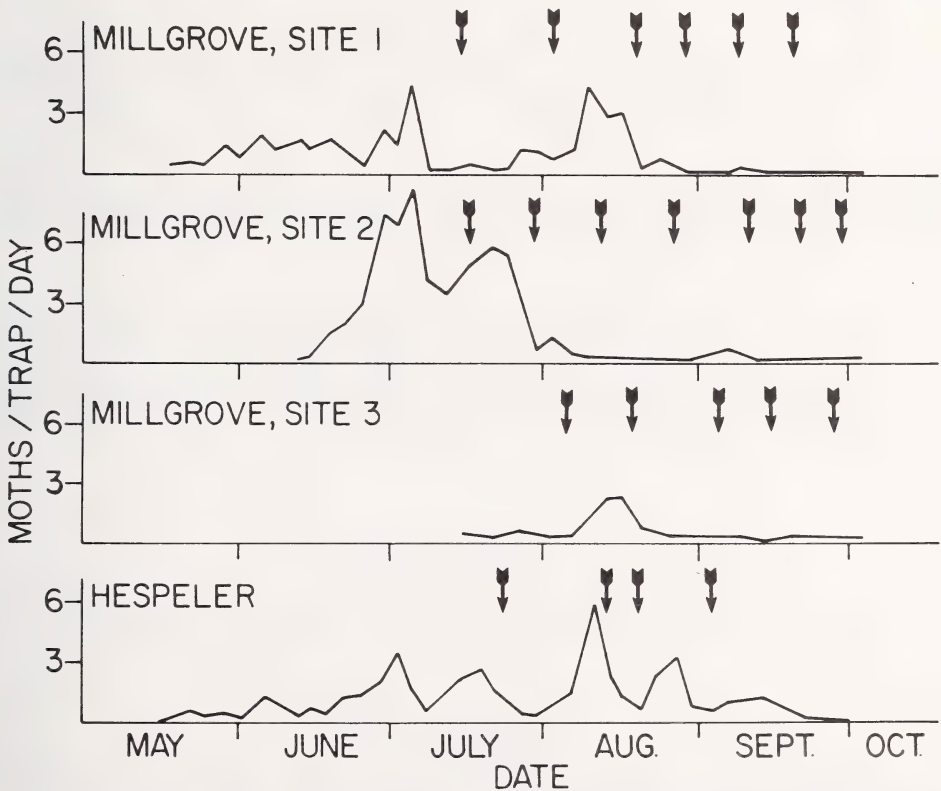


FIG. 2. Number of male *P. xylostella* captured in pheromone-baited traps in 3 commercial fields of Brussels sprouts near Millgrove, Ontario and in a research plot of Brussels sprouts at the Horticulture Research Station near Cambridge, Ontario during 1980. (Arrows indicate insecticide applications).

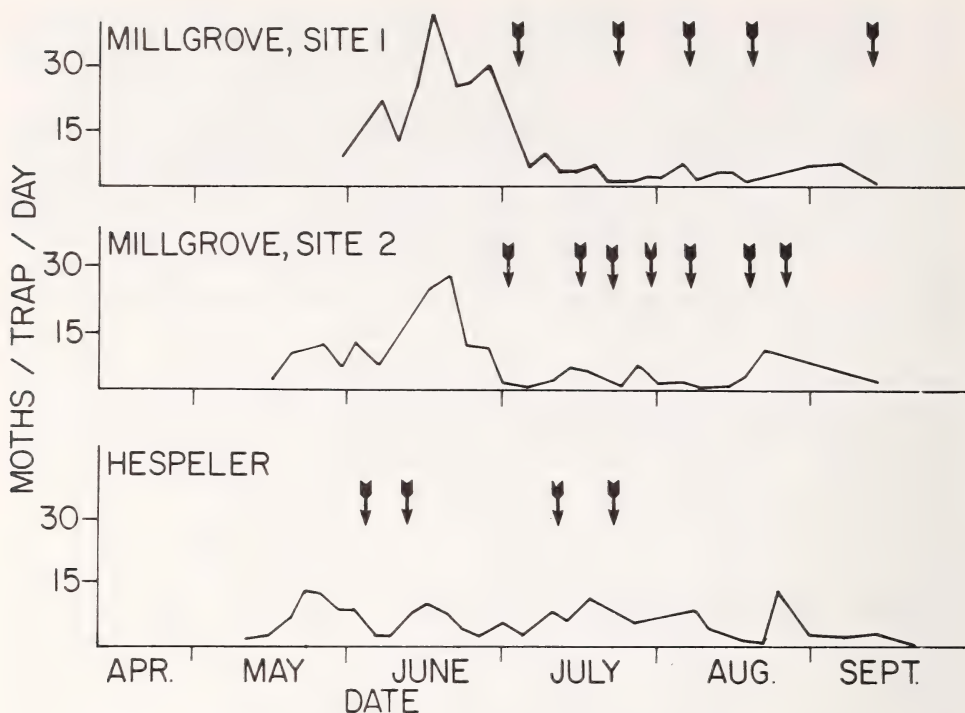


FIG. 3. Number of male *P. xylostella* captured in pheromone-baited traps in 2 commercial fields of Brussels sprouts near Millgrove, Ontario, and in a research plot of Brussels sprouts at the Horticulture Research Station near Cambridge, Ontario during 1981. (Arrows indicate insecticide applications).

moths/trap/day) subsequent to high spring collections in 1981 (Fig. 3). More crop damage was sustained in 1981 than in 1980 in commercial fields and in research plots despite regular insecticide application. The relationship between spring air flow patterns, early season moth populations, and subsequent infestations of diamondback moths could be used as a predictive tool for growers and extension personnel involved in cole crop production.

Acknowledgements

We thank the Ontario Ministry of Agriculture and Food for their support.

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A SURVEY OF GRANULAR APPLICATION EQUIPMENT AND INSECTICIDE RATES USED FOR CONTROL OF CORN ROOTWORMS (COLEOPTERA: CHRYSOMELIDAE) IN SOUTHERN ONTARIO

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Abstract

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Equipment was checked and calibrated, and the operators interviewed during actual on-farm application of insecticides for corn rootworm control. The mean application rate of 13% of the equipment was $< 80\%$ of the recommended rate, and variation between maximum and minimum rates of applicators on individual planters was $> 20\%$ of the mean for 50% of the equipment. These problems were caused by inadequate calibration and by clogging of individual applicators. Problems with the application rates were compounded by failure to use spreaders (8.2%), to use wind guards (89.2%), or to properly incorporate the insecticide (76.0%).

Introduction

Pesticide use remains the main management strategy for pest control on corn in North America (Chiang 1978). Progress has been made in developing economic thresholds and scouting programs aimed at improving the cost-effectiveness of pesticides. At the same time, efficacy of insecticides has been regularly evaluated to support label claims. However, little attention has been given to insecticide rates actually used by growers. Information on actual application rates is needed to determine whether reported instances of poor control result from inadequate rates, indicating an extension problem, or whether they are failures of recommended rates, indicating further research. In the absence of data, growers and advisors often equate poor control with resistance.

The actual application rates used by growers have not been investigated because poor application is suspected after the fact. Also, at least with mixed sprays, application rates are difficult to determine for growers randomly contacted during their actual treatments. Granular pesticides, however, present a unique opportunity; no mixing is required and thus the concentration applied is known. Furthermore, granular applicators are relatively easy to calibrate.

The objective of this research was to contact corn growers during planting, to inspect their granular application equipment and to determine the actual rates of insecticide application for corn rootworm control.

Materials and Methods

The research was confined to Huron, Oxford, Perth, Waterloo and Wellington counties in southern Ontario, Canada. Over 0.3 million ha of corn are grown in these 5 contiguous counties of Ontario. A short article was placed in several farm papers serving this area to advise growers that granular applicators of corn planters would be calibrated free of charge and in about 10 minutes as part of a research project by the University of Guelph and the Ontario Ministry of Agriculture and Food. The purpose of the notice was to arouse farmer interest and to clearly identify the project with the university, thereby increasing grower participation in the survey.

The sample was all growers who were found planting corn by a survey team. The team of 3 people used a marked University of Guelph vehicle which was parked so it would be identified by the operator when he turned at the end of the field. If granular

insecticide was being applied, permission was obtained to calibrate the application equipment. One person interviewed the operator, one inspected the equipment and one bagged the spouts of the applicators. The operator then planted ca. 50 m at regular planting speed, the bags were removed, and the actual distance travelled when calibrating was measured.

Each operator was asked the name and formulation of the insecticide being used and the intended application rate, as well as the make, model and age of the equipment, and the approximate date and method of the last calibration. The name, address and phone number of the operator was recorded to permit a follow-up report.

The following data were recorded in checking the equipment: make and model of the equipment, number of granular applicators, presence of incorporation equipment such as rakes or chains, presence of spreaders, their width and location relative to the press wheels, and presence of wind guards. The setting of each applicator unit was recorded as well as the height of the spreader (or tube) from the ground and the distance between rows. Problems such as missing spreaders and incorrect tube lengths were also recorded.

The bags of collected insecticide were labelled, returned to the laboratory and weighed. Everyone surveyed received a written report pointing out any equipment problems and showing the actual rates in grams/100 meters of row for each applicator unit of the equipment. Mean application rate of product in both kg/ha and lbs/acre, was also specified.

To determine the effect of planter speed on application rate, Counter® 15 G, Di-Syston® 15 G and Furadan® 10 G were applied in one field with a 6-row planter operated at regular planting speed. Each of the insecticides was placed in 2 insecticide hoppers of the planter. Insecticide was collected from each of the 6 applicator units while planting 50 m at speeds of 4.8, 7.2 and 9.2 km/hr. The calibrations were replicated 3 times.

Results and Discussion

The operators of 50 corn planters with granular applicators were contacted during planting in the 5-county area of southwestern Ontario and 96% participated in the survey. The high participation rate minimized bias in the survey results. A general lack of confidence in calibrating equipment was evident and a number of farmers requested calibration results for their equipment as soon as possible.

Of the 48 participants, 10 (20.8%) were not using insecticide for rootworm control because they practiced crop rotation on the field being planted and rootworms were not expected to be a problem. None of the growers surveyed used an insecticide for rootworm control on first-year corn. Only insecticides registered for rootworm control in Canada and recommended by the Ontario Ministry of Agriculture and Food (Anon. 1980) were used. Thus, extension recommendations to use crop rotation as a first method of control, not to treat first-year corn, and to use recommended insecticides have been effective.

Most of the growers applying granular insecticide (84%) were using Counter® 15 G (47%) or Dyfonate® 20 G (37%). Dyfonate® 10 G, Furadan® 10 G, Lorsban® 15 G, and Thimet® 10 G were each applied by 1 or 2 growers accounting for the remaining 16%. Recommendations to use different insecticides in successive years (Anon. 1980) would be more realistic if growers showed less reliance on 2 insecticides.

More farmers applied less than the recommended treatment rate than applied too

much (Fig. 1A). The average insecticide rate applied by 4.1% of farmers was $< 60\%$ of the recommended rate and the median application rate was 90% of the recommended rate. Some reports of poor control or 'resistance' may be explained by the 13% of equipment which was applying $< 80\%$ of the recommended rate. Moreover, some equipment with acceptable mean application rates had enough variation between applicators to suggest that poor control would occur in some rows (Fig. 1B). The difference between the maximum and minimum rates for the applicators on a particular planter were $< 20\%$ of the mean rate on 50% of the equipment tested and for 8% of the planters the differences were $> 50\%$ of the mean. This between-applicator variation of equipment applying Counter® 15 G was not different from that of equipment applying Dyfonate® 20 G (t-test; $p > 0.05$). Forty percent of growers adjusted the settings on individual applicators after inspecting the hoppers in an attempt to obtain the same flow rate from each applicator unit. Those who adjusted the applicators separately applied, on average, 89.9% of the recommended rate with 27.9% variation between rows, whereas those who used the same setting on all their units applied 105.5% of the recommended rate with 20.6% variation. Adjusting individual applicators did not reduce variability between rows. The problem apparently was partial clogging of applicators. The insecticide hoppers were removed from one planter and the openings (slots) inspected from below. Partial blocking with hardened pellets of insecticide was confirmed. Two operators also commented specifically that flow rates decreased with less insecticide in the hoppers and that 'bridging' in the hoppers was sometimes a problem. All of these factors would contribute to erratic application and thus, poor control.

One might expect that closeness of the mean application rate to the recommended rate (Fig. 1A) would be correlated with the per cent variation between individual applicators of corn planters (Fig. 1B), since both would be a function of frequency of, and care in, calibrating. A graph of these two variables showed this was not the case (Fig. 2). The R^2 for linear regression was not significant.

Farmers used 3 methods of calibration; 5.4% used the settings published in equipment manuals, 16.2% used volumetric tubes supplied by pesticide companies, and the majority, 78.4% , used the acreage meters on their corn planters. This latter group estimated the pounds required for a certain acreage and then monitored their acreage meter and the amount left in the applicator hoppers. Although rates in grams/100 meters

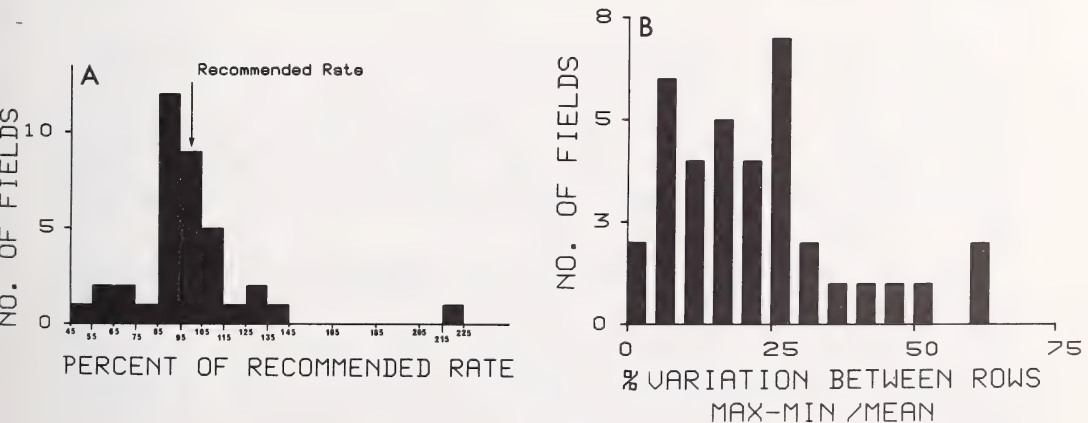


FIG. 1. Frequency distribution of number of fields being planted and A, application rate as a percentage of recommended rate, and B, per cent variation between applicators of each planter.

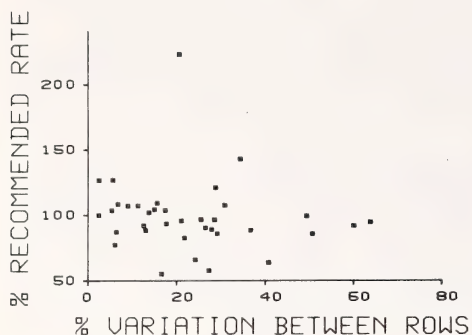


FIG.2. Relationship between per cent recommended rate applied and per cent variation between rows.

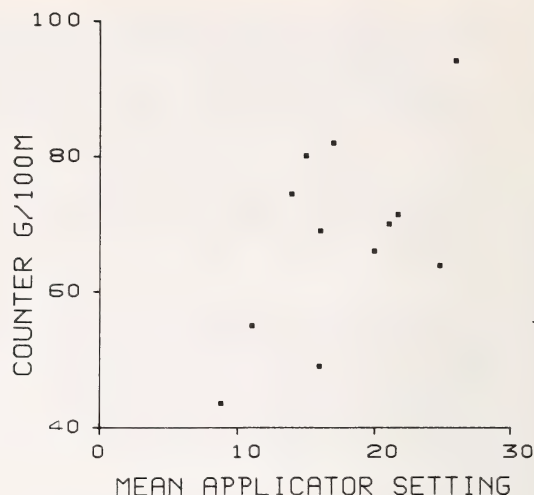


FIG.3. Relationship between mean applicator setting of John Deere® equipment and rates of Counter® 15 G applied per 100 m of row.

of row have been published yearly in Ontario since 1980 (Anon. 1980), they were not used by a single grower in calibrating and apparently they served no useful purpose. All growers gave their intended application rates in imperial units.

Applicator settings published in equipment manuals might not be adequate for calibrating equipment. The mean application rate of Counter® 15 G by 11 John Deere® 7000 planters was not correlated with the settings used (Fig. 3). In fact, a setting of 15 resulted in rates ranging from 45 to 80 g/100 meters of row. This variation would partly result from differences in planting speed. The application rates of Counter® 15 G, Di-Syston® 15 G and Furadan® 10 G all decreased with increasing planting speeds of John Deere® 7000 equipment (Fig. 4). This observation has obvious implications for farmers who either may speed up at the approach of inclement weather or may change their planting speed in response to planting conditions without first recalibrating their equipment.

As variation from the recommended application rate was not associated with a particular method of calibration (Fig. 5A), other factors must have been responsible for observed variation. One factor of significance was the length of time since the last calibration. Only ca. 50% had calibrated their equipment during the current season, at least by the time they were surveyed. The extreme variations in rates were associated with failure to calibrate equipment during the year of application (Fig. 5B). This group included all 6 growers who applied less than 85% of the recommended rate and the 1 farmer who applied more than 25% too much.

Insecticide application in a 15-cm band is recommended for rootworm control. Although spreaders producing such bands were used on 91.8% of equipment, 5.7% had at least one spreader missing, and, in some instances, the tubes carrying the pesticide were not adequately secured to the spreaders. All spreaders were from 6 to 20 cm from the ground. Farmers not using spreaders let the insecticide fall directly from the applicator tubes. In these cases, the tubes ranged from 15 to 28 cm from the ground. Two planters had applicator tubes 25 and 28 cm from the ground and were operated without protection from wind which was gusting, on those occasions, to 20 and 17 km/h, respectively. Undoubtedly the pesticide was blown to the side of the rows and resulted in

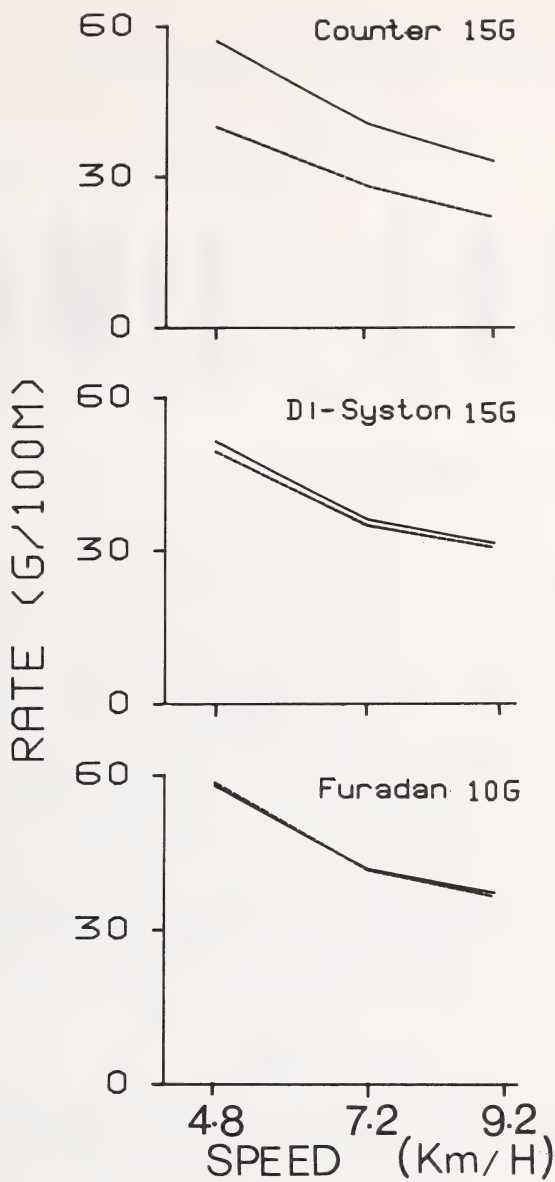
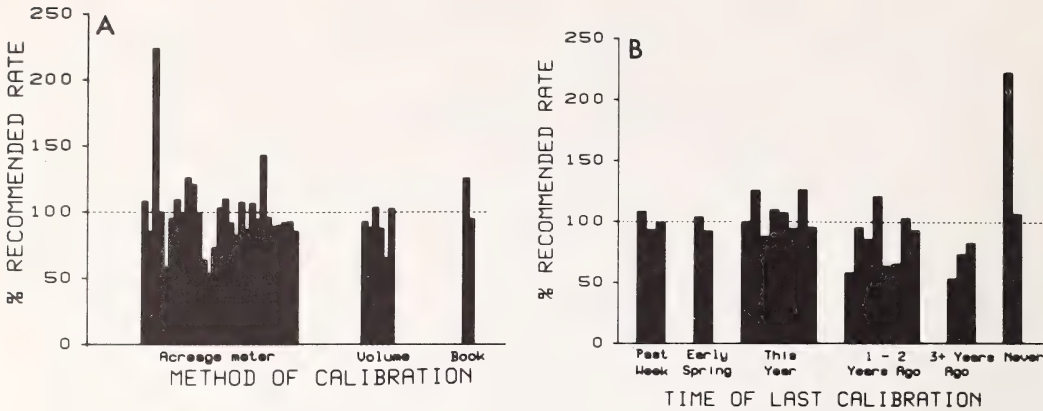


FIG. 4. Rate of application by John Deere® 7000 equipment of 3 granular insecticides at 3 ground speeds. Each line represents one applicator unit.

poor control. Canvas wind guards were used on only 10.8% of equipment used to apply granular insecticides. Considering that the average wind speed 10 m above ground, as measured at the Elora Research Station during the last 12 years, was 14.8 km/h in May, wind guards would be a good investment. Spreaders mounted behind the press wheels (29.7%) were more exposed to wind.



Seventy-six per cent of equipment did not have devices to incorporate the insecticide. Drag chains were used on only 18.1% of equipment and rakes on 5.4%. The press wheels provided some incorporation when the insecticide was applied in front of them as was the case on 70.3% of equipment. When considered together, the 13% of equipment which applied less than 80% of the recommended rate and the 50% with more than 20% variation between applicators meant that over one-half of equipment was planting some areas without a sufficient insecticide dosage. This problem of low dosages was compounded by inadequate attention to equipment and procedure; that is, failure to use spreaders (8.2%), to use wind guards (89.2%) or to incorporate (76.0%). In addition, 7.7% of equipment had one or more tubes which were too long. These tubes were curved so that insecticide settled in them between the metering device and the spreaders. This would result in erratic rates within the rows.

More attention needs to be given to actual application rates and application procedures used by growers. Between the recommended pest management programs and the results in the field are the management actions of the growers. This 'grey' area of grower action needs to be studied to understand the system, to allocate research resources and to address the appropriate problems in extension education.

Acknowledgments

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SAMPLING THE POTATO LEAFHOPPER (HOMOPTERA: CICADELLIDAE) ON ALFALFA

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Abstract

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The sweepnet was more efficient than were panshakes, water traps, sticky traps, 0.09-m² traps or cone traps for sampling *Empoasca fabae* (Harris) on alfalfa. Over a 24-hour period, the greatest numbers of potato leafhoppers were collected immediately after sunset. Costs of sampling for pest management purposes, at a standard error of 25%, ranged from \$3.50 with the sweepnet to \$590.00 with the 0.09-m² trap. The intensive sampling of all fields as a basis for management decisions would not be economically justified. However, the sweepnet was the most cost effective method for extensive sampling of alfalfa fields..

Introduction

Alfalfa in Ontario, has a diverse insect fauna with the potato leafhopper, *Empoasca fabae* (Harris), being one of the major pests. Accurate and practical sampling techniques are necessary for any pest management program, however, the value of forage necessitates that relatively inexpensive sampling methods be used for management decisions..

A number of methods for sampling the potato leafhopper have been investigated. These include: sweepnets (Simonet *et al.* 1978, 1979; Fleischer *et al.* 1982); sticky traps (Pienkowski and Medler 1966); light traps (Decker *et al.* 1971); emergence traps (Cherry *et al.* 1977); absolute D-vac samples (Simonet *et al.* 1978, 1979; Fleischer *et al.* 1982); stem bouquets (Simonet *et al.* 1978); and drop traps (Simonet *et al.* 1979; Fleischer *et al.* 1982). Frequently the populations of leafhoppers are low in southern Ontario and the large number of samples required makes these techniques time-consuming and costly.

A practical method is needed that accurately assesses field populations of potato leafhopper and provides reliable information for management of this species in Ontario. Research, therefore, was initiated to investigate various potentially useful sampling techniques. Presented here, is a report on their efficiency, reliability, cost, and some guidelines for sampling in pest management programs on alfalfa.

Materials and Methods

The study was conducted in two fields in southwestern Ontario, one in 1979 at Guelph and one in 1980 at Welland. Both fields were second-year stands of Apollo alfalfa. In 1979, the sampling area was 0.5 ha and was divided into 5 subplots. Samples from sweepnets, 0.09-m² traps, cone traps, water traps, and sticky traps were taken randomly within each subplot. Plant height and the time required to take the samples were recorded when sampling. The following 6 methods were compared weekly from 11 July to 31 August 1979:

Sweepnets. A sweepnet sample consisted of 50 pendulum sweeps taken diagonally across each subplot with a net 38 cm in diameter. Each sample was sealed in a paper bag and cooled until the insects were tabulated.

Panshakes. One, 3-stem bouquet of alfalfa was used for each panshake sample with 5 samples per subplot. Stems were selected in the field, cut at the base, and shaken into a white, enamel pan measuring 25 by 40 cm. Counts of sedentary insects in the pan were recorded in-field.

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0.09-m² Traps. Absolute samples were taken with a circular sampler of 0.09 m² (Hower and Ferguson 1972) fitted with a fine-mesh sleeve. The foliage within the sampler was sprayed for 15 seconds with Raid® containing pyrethrins (0.25%) and technical piperonal butoxide (1.25%), cut, and placed in a paper bag. A sample included those insects identified from this foliage and those recovered from the soil surface in the field. These samples were taken on the same dates as the sweepnet and panshake samples.

Cone Traps. Four inverted Berlese funnels were placed in each of 4 subplots. On each weekly sampling date the funnels, each with a base area of 830 cm², were dropped onto the chosen sites and sealed at the base with surrounding soil. Strips of polyethylene, coated with Tangle-Trap®, were placed in 448-ml jars and these jars were then screwed onto the tops of the funnels. The strips were collected from the jars the following day.

Sticky Traps. These were yellow boards mounted horizontally, 30 cm high, on stakes. Three of these traps, each 900 cm², were placed in each subplot. Sheets of clear polyethylene coated with Tangle-Trap® were stapled to the top of each board. After 4 days in the field, the sheets were removed. Sampling was done on a weekly basis except during the harvest period when the boards were removed from the field.

Water Traps. Three yellow, plastic pans, measuring 32 by 26 cm, were placed in each subplot. These were buried so that their rims were level with the surrounding soil and were half-filled with a solution of 50:50 ethylene glycol: water. A tablespoon of liquid detergent was added to each pan to lower the surface tension. The water traps remained in the field during the same 4-day period as the sticky traps. Insects were netted from the pans and returned to the laboratory.

Insects from all sampling methods were identified and counted in the laboratory. These methods were then evaluated by comparing weekly numbers of potato leafhoppers and calculating the precision and cost for each technique. As the distribution of the leafhopper in alfalfa samples fitted a negative binomial distribution, the data were transformed by $\sqrt{x + 0.01}$ before analysis. Analysis of variance was performed and where significant F values were obtained, weekly differences were determined by Duncan's New Multiple Range Test.

In 1980, sweepnet sampling was investigated to determine the time of day when the greatest number of leafhoppers could be collected. Samples were collected for a 38-hour period beginning 27 August when the alfalfa was 15 cm tall. Five sets of 50 pendulum sweeps were taken hourly by the same individual.

Results and Discussion

Populations did not exceed 9.3 leafhoppers per 50-sweep sample or 0.2 per sweep (Table I). With the exception of the sweepnet, the sticky traps collected significantly more leafhoppers than did the other methods. At the same time, numbers collected in the 0.09-m² traps, the cone traps, and with the panshakes were significantly less. In fact, fewer than 0.5 leafhoppers per sample unit were collected by these 3 methods throughout the entire summer. The small sample unit accounted to some extent for these low numbers. The cone traps sampled only adults whereas the panshakes collected only nymphs. Comparisons between sweepnets, sticky traps, and water traps were not made since the conversion to absolute numbers for the latter two required an estimation of the sampling area, and thus, trap attractiveness (Strickland 1961).

Plant height was a significant factor in determining the number of leafhoppers captured by each method. The 0.09-m² trap, the cone trap, and the panshake method apparently were unaffected by plant height since populations did not change over time

whereas in both the sweepnets and sticky traps, leafhopper numbers increased proportionately with alfalfa height. Mean numbers of leafhoppers (4.2/sample unit) collected by the water trap indicated an increased efficiency for this method at lower plant heights when compared to taller plants on later sampling dates. At lower heights, insects landing on the surface of the traps would not be obstructed by the foliage as happened in taller stands.

The mean numbers in the sweepnet samples decreased to 1.7 leafhoppers/50 sweeps the week after harvest. This decrease indicated a reduction in efficiency at plant heights of about 10 cm or less (Southwood 1978). The efficiency of sticky traps, however, was unaffected by harvest. More *E. fabae* continued to be collected immediately following harvest, although a reduction was observed when the alfalfa height was approximately that of the traps (30.4 cm). The initial, high numbers of 11.4 leafhoppers/trap collected after the harvest probably represented movement into the field from surrounding areas. Poston and Pedigo (1975) showed the *E. fabae* dispersed into adjacent fields of alfalfa immediately after cutting.

Southwood (1978) reported that estimates of population density with standard

TABLE I. Number of potato leafhopper adults and nymphs collected per sample unit by six methods during six weekly periods in regrowth alfalfa at Guelph, Ontario, 1979

Sampling Method	N	Mean Number of Potato Leafhoppers*					
		July		August			
		9-16th	17-24th	1-8th	9-16th	17-24th	25-31st
Sweepnet	6	0.5ab**	2.3ab	1.7ab	6.3b	9.3b	6.0b
0.09-m ² Trap	12	—	0.0a	0.0a	—	0.2a	0.2a
Cone Trap	16	0.3a	0.1a	0.3a	0.3a	0.5a	0.2a
Panshake	30	—	0.1a	0.0a	0.0a	0.0a	0.1a
Water Trap	18	0.6ab	0.1a	4.2b	1.2ab	0.3a	—
Sticky Trap	18	2.0b	2.0b	11.4c	6.4b	16.1b	10.1b
Plant Height (cm)	30	40	44	10	30	36	49

* Analysis on transformed data; $\sqrt{X} + 0.01$.
** Means within a column followed by the same letter are not different ($p \leq 0.05$) as determined by Duncan's New Multiple Range Test.

TABLE II. Average number of samples required for coefficients of variation of 10, 20 and 30% by six sampling methods in regrowth alfalfa at Guelph, Ontario, 1979

Sampling Method	Mean No. of Sample Units Required		
	10%	20%	30%
Sweepnet	33	8	4
0.09-m ² Trap	1875	469	208
Panshake	2769	692	308
Cone Trap	613	153	68
Water Trap	168	42	19
Sticky Trap	21	5	3

TABLE III. Comparison of cost, mean relative variation, and relative net precision of six methods for sampling potato leafhoppers in alfalfa at Guelph, Ontario, 1979

Sampling Method	N*	Mean No. Collected Over Summer (X + SE)		Cost (Man-Hours/ Sample)	RV**	1*** RVCs
Sweepnet	36	4.36	0.63	0.17	14.45	0.41
0.09-m ² Trap	48	0.08	0.03	0.25	37.50	0.11
Panshake	150	0.05	0.03	0.03	60.00	0.56
Cone Trap	96	0.28	0.16	0.17	21.43	0.28
Water Trap	90	1.29	0.31	0.33	24.03	0.13
Sticky Trap	108	7.99	0.95	0.33	11.89	0.25

* N is the number of samples used in each comparison (number for the entire summer).

** RV = $(SE/\bar{X} \text{ No. Insects}) \times 100$ is relative variation

*** Relative net precision where Cs is cost in man-hours/sample (Pedigo *et al.* 1972)

TABLE IV. Cost for six methods of sampling populations of the potato leafhopper at Guelph, Ontario, 1979

Sampling Method	Time to Take Sample (Min.)	No. Samples Required at C.V.* of 25% in Area of 0.5 ha	Time to Sample at C.V. of 25% (hr/ha)	Cost in Man-Hours/ha (\$3.50/hr)
Sweepnet	10	6	1.00	3.50
0.09-m ²	15	339	169.50	593.25
Panshake	2	500	37.00	129.50
Cone Trap	10	111	33.33	116.66
Water Trap	20	31	20.67	72.35
Sticky Trap	20	4	2.67	9.35

* C.V. = Coefficient of variation.

errors of 25% or less were sufficient for extensive sampling where rapid estimates were required. Intensive sampling for detailed ecological studies, however, required a standard error of 10% or less. Realistic sample sizes, in terms of man-hours for management decisions, were found only for the sweepnet and sticky trap methods. These averaged 8 and 5 samples, respectively, over the entire season at a coefficient of variation of 20% (Table II). The 0.09-m² trap, cone trap, and panshake method required greater than 150 samples at the same coefficient of variation.

Relative variation, R.V. = $(SE/\bar{X} \text{ No. Insects}) \times 100$, over the entire summer was used to compare sampling methods for variability. None of the sampling methods studied was adequate for intensive studies although all except the 0.09-m² trap and the panshake method had a sufficiently low relative variation to be reliable for extensive sampling (Table III). The method with the lowest variability would require fewer samples to obtain the same information, or would provide more information if the sample sizes were equal (Pedigo *et al.* 1972). Thus, the sampling methods in decreasing order of efficiency based on relative variation are sticky traps, sweepnets, cone traps, water traps, 0.09-m² traps, and panshakes.

The cost of the sampling methods was dependent on the equipment and the time involved in collecting and identifying the samples. Rather than comparing the cost directly, relative net precision ($1/RVCs$ where RV = mean relative variation of transformed data and Cs = cost in man-hours per sample) as described by Pedigo *et al.*

(1972) was used initially. In terms of cost and variability, the sampling methods are arranged in the following order of decreasing usefulness (Table III): panshakes, sweepnets, cone traps, sticky traps, water traps, and 0.09-m² traps. The panshake method was by far the least expensive since a minimal time of 0.03 man-hours was required to take each sample. The high relative variation of 60.0 for this method, however, and the fact that it was only efficient in sampling for nymphs, make direct comparisons with the other techniques of little value. Hence, in terms of relative net precision, the sweepnet was superior to the remaining methods and with a cost of \$0.41/sample, had the greatest precision for unit effort.

Extensive sampling costs for the 6 methods are summarized in Table IV. At \$3.50/ha, the sweepnet was the least expensive method for assessing leafhoppers in the field. Kieckhefer and Medler (1964) reported that distinct aggregations of leafhoppers can occur at the margins and hills and ridges of fields. If the area sampled is fairly uniform, an accurate estimate for management of most fields could probably be obtained with the same number of samples used in 0.5 ha. At the population levels present in 1979 in Guelph, 6 sets of 50 pendulum sweeps would be sufficient for estimating the numbers of leafhoppers. As the average farm in Ontario has from 12 to 30 ha of forage alfalfa, the time required by the grower to take 6 random samples in his fields would then be approximately 1 hour at a cost of approximately \$3.50.

Since the sweepnet method was the most efficient for identifying economic populations of the leafhopper, this method was further investigated in 1980 to determine the most efficient time to sample. The numbers of potato leafhoppers collected over a

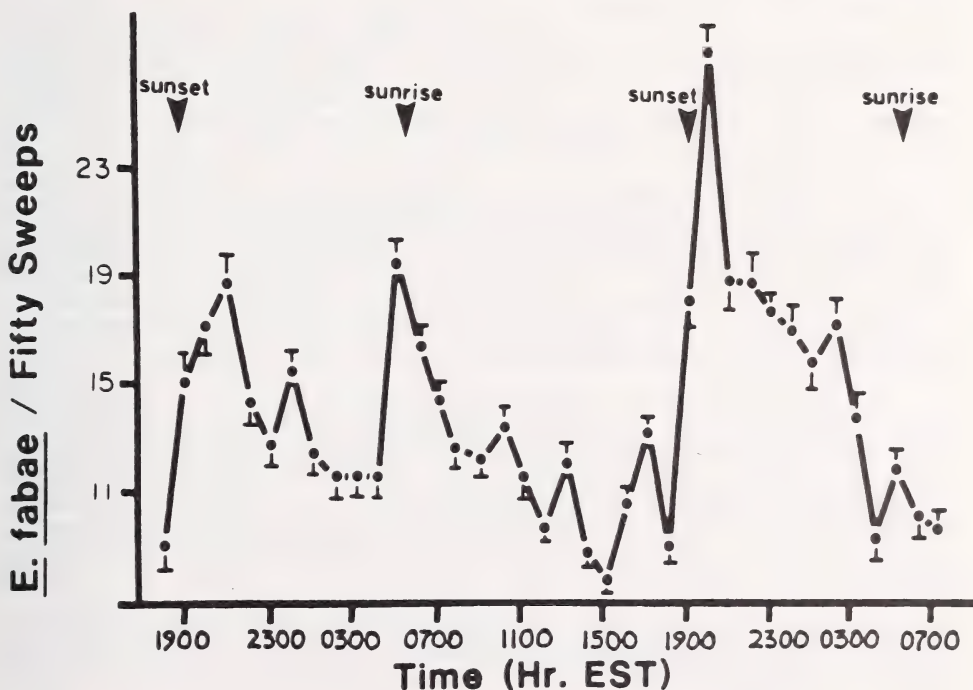


Fig. 1. Average number of potato leafhoppers collected in 5 samples of 50 pendulum sweeps during a 38-hour period on 27, 28, and 29 August near Welland, Ontario, 1980.

38-hour period are shown in Fig. 1. Average temperatures during the sampling period ranged from a maximum of 30°C to a minimum of 20°C. No rainfall was reported during this same period. Generally, 25% more leafhoppers were captured during the night than during the day, with night samples averaging 15 per 50 sweeps and day samples, 11 per 50 sweeps. Distinct peaks in numbers occurred consistently for periods of one to two hours following each sunset.

Dysart (1962) found that approximately 90% of all flight activity of the leafhopper took place during the dark hours with 50% of that occurring about 30 minutes after sunset. In addition, he observed a smaller peak in activity around sunrise and a reduction in activity under windy conditions. For reasons of convenience, sampling for the potato leafhopper has most often been carried out during daylight hours (Saugstad *et al.* 1967; Simonet *et al.* 1978, 1979). Our studies, however, indicated that greater efficiency in sampling would be obtained at sunset or during the evening. At this time, fewer samples would be required for accurate estimates of the population. This would also mean, however, that with the same degree of injury, a greater number of leafhoppers would be reported and thus, if samples were taken in the evening hours, the present threshold of one leafhopper/sweep would be too low.

Southwood (1978) reported that despite its limitations, the rapid knockdown of insects with pyrethrum could be a reliable, absolute method for certain species. Based on this technique with pyrethrum, the 0.09-m² traps were expected to provide an absolute estimate of leafhopper densities. With populations below 1.8 leafhoppers/m² for the entire season, the numbers of potato leafhoppers were not assessed accurately by this technique.

Cherry *et al.* (1977) reported that emergence traps, similar to the cone trap used here, when set in place 15 minutes, collected 80% of the actual populations of leafhoppers. Simonet *et al.* (1979) found this method inefficient and concluded that the length of time the trap remained in place affected sampling efficiency. The cone traps in the present study remained in place 24 hours to overcome this difficulty, but they were still inefficient in sampling for potato leafhoppers.

In the present study, the sweepnet was the easiest and most efficient method of sampling for the leafhopper on alfalfa. It is recognized, however, that this method does not sample nymphs adequately and a specific method, for example, the panshake method would also be required for nymphs (Simonet *et al.* 1978). Although the sweepnet is widely used to estimate insect populations in field crops (Strickland 1961), its efficiency is affected by several factors including temperature, humidity, plant height, and the individual using the sweepnet (DeLong 1932; Southwood 1978; Cothran *et al.* 1975).

Sweepnets are the most practical sampling method for scouts or growers who require extensive estimates of leafhopper populations for pest management purposes. Potato leafhoppers must be identified in samples containing many species, however, and unfortunately few growers have the training to do this. If farmers were to use sweepnets as an aid in making pest management decisions, an extensive program of extension education would be required. Also, since growers are not restricted by an 8 to 5 work day, several thresholds would be needed to account for changes in sampling efficiency during the evening.

Sampling costs must be considered as part of the costs of any pest management program. Because alfalfa has a relatively low value, \$3.50 for an individual decision using sweepnet sampling is generally prohibitive. Growers are more likely to become aware of particular insect problems on regrowth alfalfa through extension personnel, the media or symptoms seen through superficial inspections. Since sweepnet samples provide the

cheapest answers and the method is simple to use, it would, however, be the most useful one for those who have to make decisions on particular fields.

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**CONTROL OF POTATO STEM
BORER, *HYDRAECIA MICACEA* (LEPIDOPTERA: NOCTUIDAE),
IN FIELD CORN**

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Abstract

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Infestations of *Hydraecia micacea* (Esper) were of two types in Ontario corn fields; either field-wide and resulting from oviposition on grasses within the fields, or restricted to border rows to which larvae dispersed from weedy fencerows. Field-wide infestations were correlated with areas containing weeds, especially quack grass. Weed control was indicated for the best long-term control of these infestations. Weed control in fencerows reduced subsequent mortality of corn plants by potato stem borer by only 30% and only on 2 of 4 test farms. Damage by borers dispersing from fencerows was reduced by burning grasses to destroy eggs or by excluding larvae from the crop with mechanical barriers. Partial compensation for seedling loss in border rows was obtained by double planting such areas. The most effective insecticide treatments were sprays of the fencerows in early May to kill larvae while they were still in the grasses.

Introduction

The biology of the potato stem borer, *Hydraecia micacea* (Esper), in Canada has been discussed by Jobin (1963) and Deedat *et al.* (in press). It is a univoltine, polyphagous noctuid which overwinters as eggs on grasses. The first-instar larvae feed on grasses in the spring but, by the third instar, some have dispersed to attack corn. The attack and damage to field corn have been discussed by Deedat and Ellis (in press).

Weed control in fields has been the only method recommended for controlling potato stem borer. However, severe infestations occurred in some fields in spite of attempts to control weeds (Tetor 1980; Muka 1976) and complaints from Ontario farmers have increased in recent years. The objective of this research was to investigate various control methods for managing this pest in field corn.

Materials and Methods

The effect of weeds on damage to field corn by potato stem borer was studied in 3 fields: 2 near St. Jean, Quebec, and one near Alma, Ontario. Each field had at least one weedy border. Plots were established in the corn adjacent the weedy border. In the Quebec fields, 3 treatments were used: one a 'weedless' area (< 2 weed stems/625 cm²), one an area infested with field horsetail, *Equisetum arvense* L., and one an area infested with quack grass, *Agropyron repens* (L.) Beauv. The areas used for each treatment were 10 m long x 5 rows wide and were located on naturally occurring weed populations. They were repeated at 4 distances from the weedy border of both fields with one replicate located half way across the field to include row 69 in one field and row 118 in the other. To compare stem borer populations in the border rows of corn where infestations of horsetail and quack grass were not present, 3 additional 'weedless' treatments were used. Two plots, 25 m long x 20 rows wide with different densities of quack grass were compared at Alma, Ontario. At each site, the number of damaged plants and the per cent plant mortality were calculated from initial plant counts and the number dead or dying later in the season. The density of weeds was determined in mid June from 5 randomly selected, 625-cm² areas in each Quebec plot and in 10, 1-m² areas in each Ontario plot. In addition, the density of field horsetail, quack grass and *Agrostis* sp. of grass was determined in the weedy border of the Quebec plots.

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Burning of weeds in the fencerows to destroy eggs of the potato stem borer was tested at Lancaster, Ontario. Two adjacent fields with a similar history of damage from potato stem borer were used. The grassy fencerow of one field had been burned in the fall of 1979 and two plots, 25 m long x 20 corn rows wide, were established in 1980 adjacent the fencerow of each field. In 1981, 6 plots, 20 m long x 20 rows wide, were located adjacent a fencerow of a cornfield at Moorefield, Ontario. The grasses in the fencerow of 3 of these plots were burned on 26 April. Corn plants were counted in each row of all plots after corn emergence and again after plant mortality due to potato stem borer had ceased.

Barriers, made of plastic lawn-edging, were placed between the fencerow and the first row of corn to determine if the movement of the borer into the field could be prevented. Two treatments, one with the barrier and one without, were replicated 5 times in a completely randomized design of plots each 20 m long x 10 corn rows wide. All plots were separated by 5 m. Each barrier was the length of the plots, and extended 5 cm below ground and 10 cm above. The experiment was repeated at 2 locations: one near Moorefield and one near Palmerston, Ontario on 26 May 1981. Effectiveness in reducing borer damage was determined by counting plants as in the previous experiment on burning.

Corn bordering the fencerow was double planted to determine if this would prevent the larvae from moving further into the fields. Double planting was achieved by passing the corn planter twice over the plots so that rows contained twice as many plants. Each plot was 20 m long by 6 or 12 rows wide, and separated by 5-m strips. The treatments of double and regular planting were replicated 5 times and the experiment repeated at 4 fields in Ontario: 2 in Wellington county, and 2 in Perth county. Double planting was done on the first 6 rows of one field in each county and the first 12 rows of the others. In each field, initial and final plant counts were made in the 6- or 12-row plots as well as the adjacent rows up to row 20.

Damage by the potato stem borer was monitored in 3 cornfields: the Skerritt and Trask farms near Alma, Ontario during 1980 and the Oliff farm near Moorefield, Ontario in 1981. Six plots, 20 m long x 20 rows wide, were established along the edge of each field and the initial number of plants was counted in each row. The number of damaged plants was counted every other day from 29 May to 16 July 1980 at the 2 sites near Alma, and from 24 May to 10 July 1981 at the Moorefield site. Damaged plants containing larvae were removed from 3 of the plots to determine whether or not subsequent damage would be affected.

Glyphosate and paraquat were applied to weedy fencerows to determine whether the primary hosts of the potato stem borer could be killed in the spring in time to influence the survival of borers and their dispersal into field corn. Both herbicides were used as registered in Canada; glyphosate at 2.2 kg a.i./ha in 240 L of water, and paraquat at 1.1 kg a.i./ha in 1200 L of water. In 1980, the 2 herbicides were applied at various times in the spring at 3 fields. In 1981, earlier spring applications of the 2 herbicides were tested at 2 fields, and spring and fall applications of glyphosate tested at 2 additional fields. In each field, herbicide treatments were replicated 3 or 4 times and randomized along a weedy fencerow. Treatments were applied to the entire width of 10-m strips of fencerow in 1980 and of 20-m strips in 1981. The initial plant stand was determined in each of the 10 rows adjacent to the treated border before the potato stem borer began its attack. Plants were recounted in late July of both 1980 and 1981, after the pest had completed its development, and the data were tabulated as per cent plant mortality.

Insecticides were applied along the width of weedy fencerows of 5 corn fields in different areas of Ontario to determine if the early instars of the potato stem borer could

be killed in time to prevent their movement into the corn. Cypermethrin at 70 g a.i./ha, permethrin at 140 g a.i./ha, and chlorpyrifos at 1.1 kg a.i./ha were applied on various dates in May. Treatments at Drayton were replicated 4 times, those at Moorefield and Palmerston 5 times and those at Bainsville and Lancaster 6 times. Efficacy was determined from initial and final plant counts as for the herbicide tests.

Carbofuran and chlorpyrifos were banded over the rows of field corn to determine whether or not these insecticides as applied for rootworm control would also control potato stem borer. Chlorpyrifos was tested at 7.4 g a.i./ha in 15-cm bands and carbofuran at 8 g a.i./ha in 15-cm bands and at 16 g a.i./ha in 15- and 30-cm bands. Treatments were replicated 3 times and randomized along 4 rows of corn adjacent to a weedy fencerow in 10-m-long plots. Insecticides were banded over the rows within 6 days of planting, and raked into the top 2.5 cm of soil. The experiment was repeated in a field at Alma, at Elora and at Lancaster. Efficacy was determined from initial and final plant counts and expressed as per cent plant mortality.

Results and Discussion

Importance of Weeds. Plant mortality due to potato stem borer occurred from the grassy fencerow to the middle of the two Quebec fields (Fig. 1 A&B). This is in contrast to a field in southwestern Ontario, at Alma, where there were more damaged plants in weedy rows

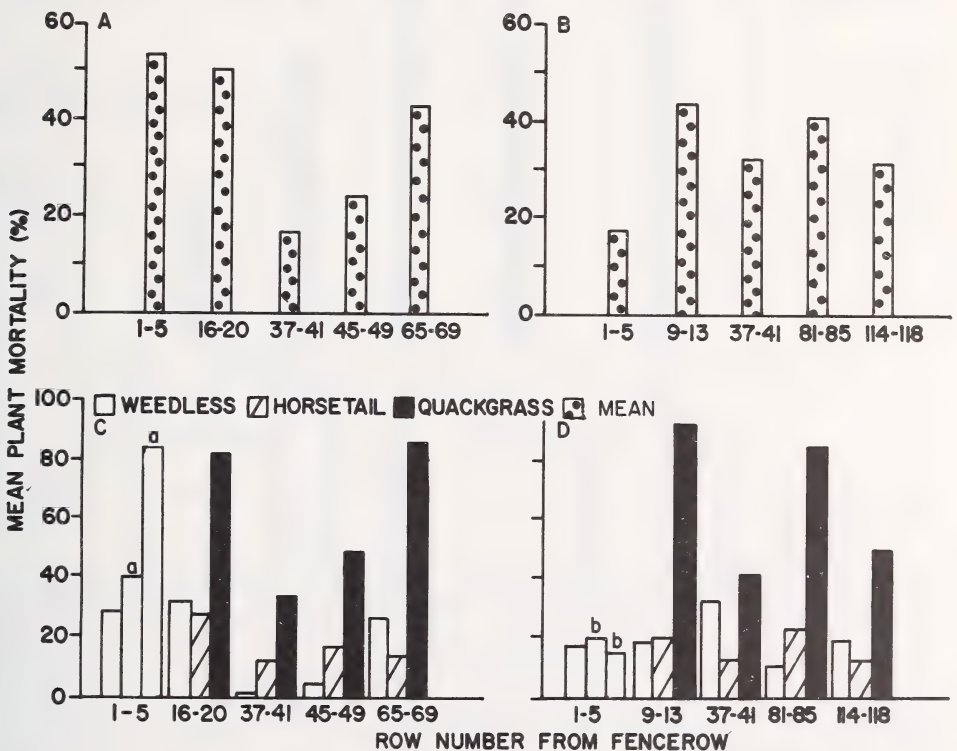


Fig. 1. Mean mortality of corn plants at St. Jean, Quebec, by *H. micacea* at various distances from the fencerow: A&C, Field 1; B&D, Field 2; A&B, mean mortality; C&D, mortality in plots infested with various weeds. Weeds in adjacent fencerow of weedless border rows indicated by a, quack grass and b, *Agrostis* sp.

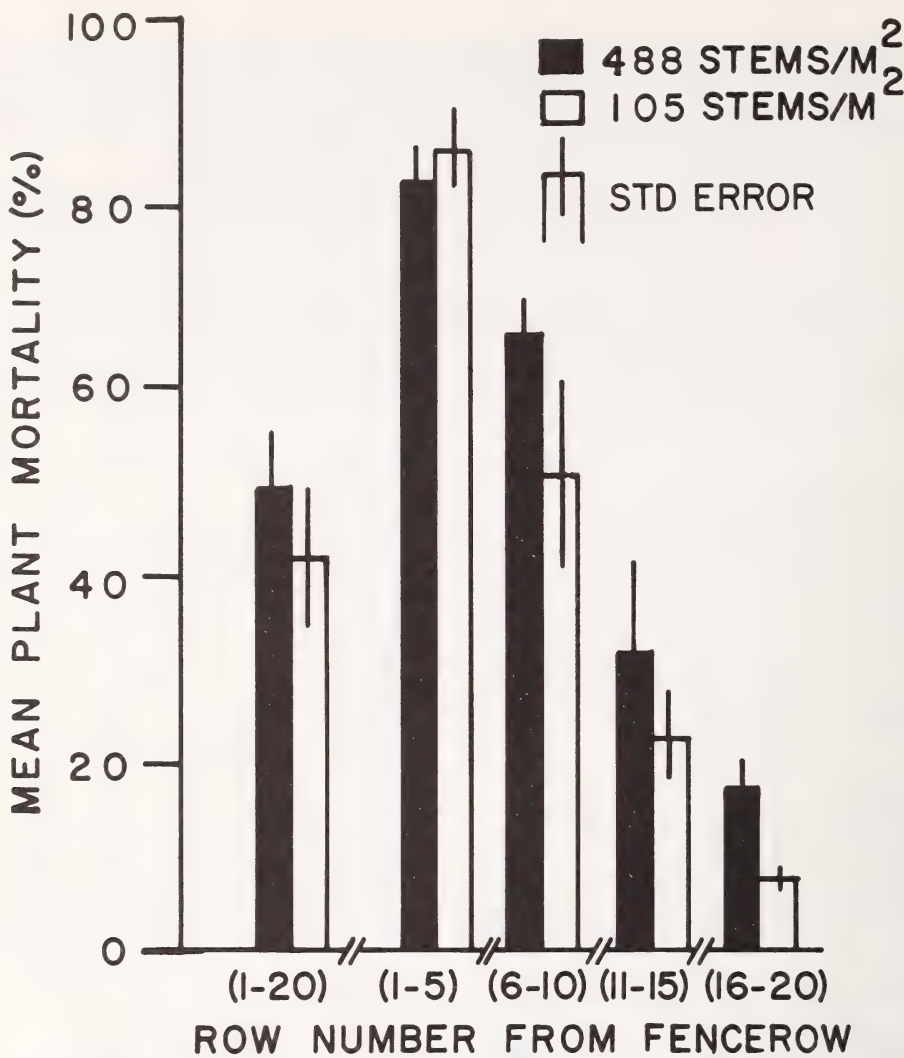


Fig. 2. Mean mortality of corn plants by *H. micacea* at Alma, Ontario in plots with two densities of weeds.

6 to 12 although the most significant factor was a decline in damage with increasing distance from the fencerow (Fig. 2) and damaged plants were rare beyond row 40. This latter border effect is common in Ontario (Fig. 5) and has been described by Ellis and Deedat (in press). The fact that damage was field-wide in the weedy Quebec fields and often greater within the field than closer to the fencerow, indicated that eggs can overwinter on weeds throughout the fields. In this case, one would expect damage throughout the fields to be dependent on the species of weeds present and their abundance. A comparison of damage in plots containing < 2 weed stems/625 cm² with weedy areas containing mostly quack grass, *Agropyron repens* (L.) Beauv., or field horsetail, *Equisetum arvense* L. showed damage was much greater where quack grass was present, regardless of the distance from the fencerow (Fig. 1 C&D). Furthermore, when the percentage of damaged plants in each plot was compared to weed stems/625 cm², the

damage increased with quack grass density to a maximum of 85 to 90% at 15 to 30 stems/625 cm². A relationship between quack grass and borer infestation was expected since quack grass is a preferred host (Jobin 1963; Deedat *et al.* (in press)). Damage in weedless and horsetail-infested plots was not significantly different and damage in the horsetail plots was 20 to 30% at densities from 0 to 25 stems/625 cm² (Fig. 3). No horsetail plant was found that had been attacked by borer and this further indicated that horsetail is not a host of the potato stem borer. *Agrostis* sp. of grass in the fencerow did not affect damage in border rows (Fig. 1D) whereas quack grass did (Fig. 1C).

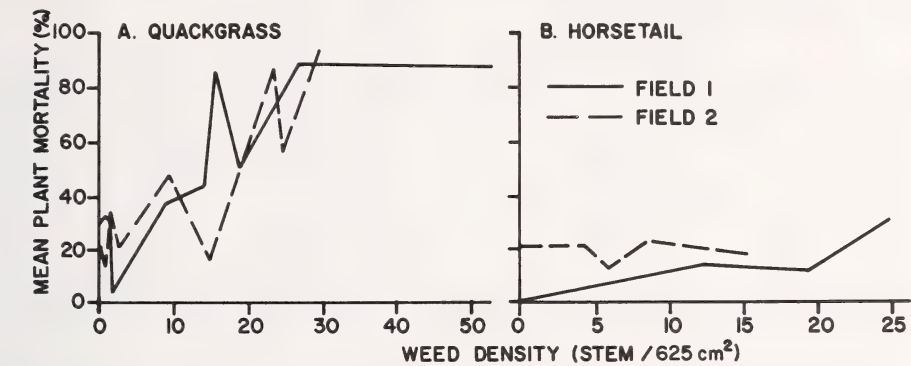


Fig. 3. Mean mortality of corn plants by *H. micacea* compared to weed densities in 10-m-long x 5-row plots on two fields near St. Jean, Quebec.

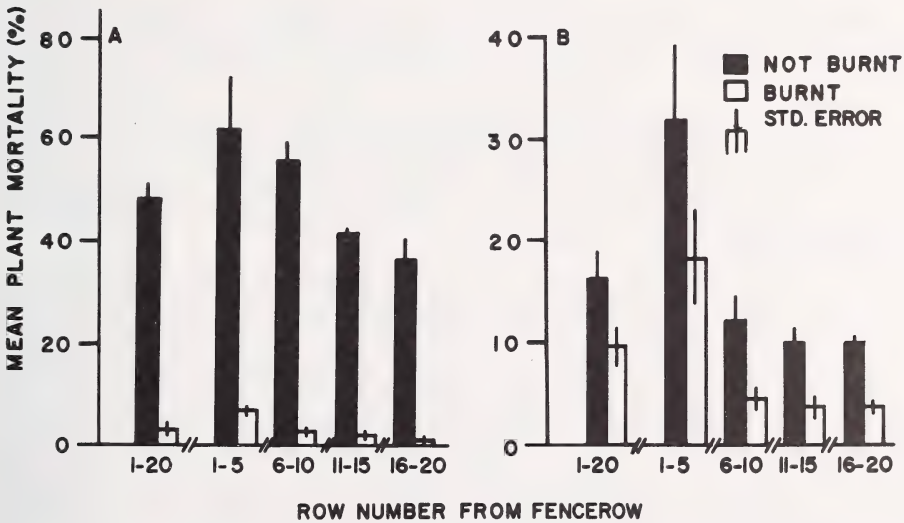


Fig. 4. Mean mortality of corn plants due to *H. micacea* in the first 20 rows of corn following burning of the weeds in the fencerow. A, fall burning of entire fencerow of one field compared to another field with fencerow not burned, 1980; B, spring burning of 20-m strips of fencerow compared with strips not burned, 1981.

To date, weed control in fields is the only method of control recommended for this pest (Bereza 1975). Data presented here indicate that improved weed control,

TABLE I. Per cent mortality of corn plants by *H. micacea* in Ontario following application of paraquat or glyphosate at various times to fencerow weeds.

Year	Herbicide	Treatment	Mean Per Cent Plant Mortality ¹			
		Time of Application	Field 1	Field 2	Field 3	Field 4
1980	Glyphosate	Spring (8-16 May)	50.4 b	44.8 c		
		Spring (21-28 May)	45.6a	34.5 b	7.7a	
		Spring (6-12 June)	51.3 b	37.4 b		
	Paraquat	Spring (8-16 May)	40.3a	27.8a		
		Spring (21-28 May)	52.9 b	36.5 b	11.0a	
		Spring (6-12 June)	43.4a	47.7 c		
	Control		44.8a	29.2ab	8.7a	
1981	Glyphosate	Spring (22 April-3 May)	40.7a	14.9 b	35.9a	22.3a
		Fall (13 Nov.)			43.3a	15.8 b
	Paraquat	Spring (22 April-3 May)	40.2a	16.0 b		
	Control		34.1a	20.8a	41.4a	21.3a

¹ Percentages were transformed by arcsin $\sqrt{\text{percentage}}$ for analysis of variance. Treatment means for a particular year and field followed by different letters are significantly different, $P < 0.05$.

particularly of quack grass, within fields would lessen the severity of field-wide damage. However, good weed control within fields will not prevent damage adjacent to weedy fencerows. This is an important point in planning control of this pest.

Control of weeds in fencerows by spraying with glyphosate or paraquat in mid May or June either had no effect on subsequent mortality of corn plants or resulted in greater damage (Table I). This probably was because treatments were too late to cause borer mortality but caused faster dispersal into the corn fields. Similar treatments applied in late April to early May or the previous November were also not economical because the subsequent mortality of corn plants was reduced by less than 30% and this reduction occurred on only 2 of 4 fields. Glyphosate killed the perennial grass hosts and reduced borer damage in subsequent crops. However, such permanent removal of grassy field margins is not desirable because of increased erosion and because problems with annual weeds usually develop when perennial grasses are suppressed.

Destruction of Eggs. Burning of weeds in fencerows significantly reduced ($P < 0.1$) the subsequent mortality of corn plants due to potato stem borer (Fig. 4). Less borer damage occurred where the entire fencerow was burned (Fig. 4A) than when 20-m burned sections were alternated with unburned controls (Fig. 4B). Plant mortality in the corn adjacent to the burned strips of the latter experiment likely resulted from dispersal of borers from the controls. Since eggs are laid on grass where they overwinter, burning the grass destroys them. Where burning is practical and the borer problems arise from the field margins, burning is an excellent method of control. Unfortunately, burning is not generally practical for a number of reasons including increased erosion, the risk of burning wooden fences or fence posts, shared property line, and the need for permits to burn.

Preventing Entry into Fields. Plastic barriers placed between the fencerow and first row of corn prevented movement of borers into test fields. The mean mortality of plants in plots with barriers at the Moorefield and Palmerston sites was 5.4 and 8.1%, whereas, in plots without barriers, the mean was 24.5 and 28.7%, respectively. The barriers were effective in both fields ($P < 0.05$) and reduced plant mortality by more than 70%. Although these

barriers would be impractical except perhaps in home gardens, the data demonstrate the potential of exclusion as a method of control for potato stem borer. In areas where infestations come from fencerows, some other barriers such as insecticidal baits or furrows with contact insecticide should be investigated.

TABLE II. Mean mortality of corn plants in border rows due to *H. micacea* in regular and double-planted corn in four Ontario fields.

Field	Area and County	Hybrid and Planting Date	Rows Double Planted	Plant Mortality (%)		
				Sample Location ¹	Regular	Double
1	Rothsay	Pioneer 3957	1-6	1-6	20.0	18.2
	Wellington	6 May 1981		7-20	5.7	7.7
2	Palmerston	Cargill 810	1-6	1-6	33.9	29.1
	Perth	20 May 1981		7-20	11.1	11.2
3	Moorefield	DeKalb 24	1-12	1-12	11.4	11.8
	Wellington	20 May 1981		13-20	3.9	3.4
4	Palmerston	Pioneer 3927	1-12	1-12	13.0	12.9
	Perth	20 May 1981		13-20	4.2	2.9

¹ Rows from the edge of the field.

Compensation by Double Planting. Double planting the first 6 or 12 rows of corn bordering fencerows neither reduced plant mortality significantly in the first 6 rows nor prevented damage further into the fields (Table II). With more plants, proportionally more of them were damaged. However, double planting is a potential management strategy along grassy margins where borers are an annual problem because more plants remained than in the regular-planted plots and compensated for plant mortality due to borers.

Insecticides. Removal of damaged plants, together with the borers associated with them, did not decrease plant mortality in these plots (Fig. 5). It was hypothesized that removing

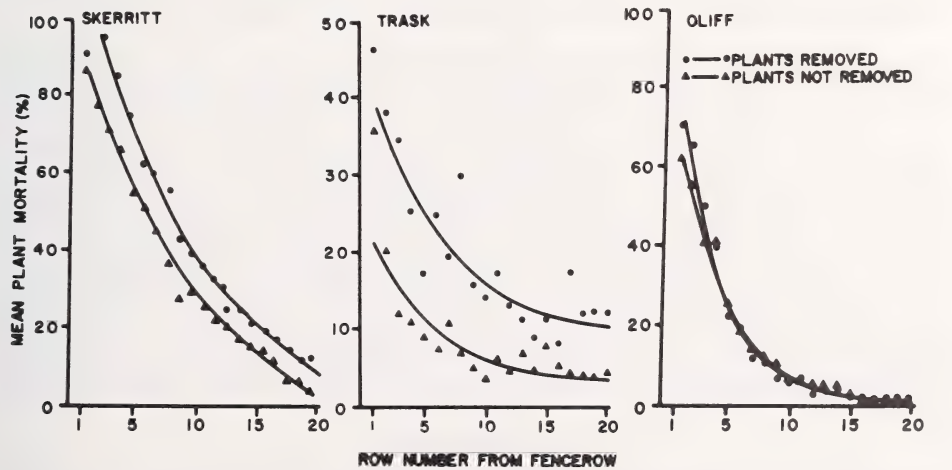


Fig. 5. Mean mortality of corn plants due to *H. micacea* in the first 20 rows of 3 farms where infested plants were either left or removed along with the borer within 3 days.

TABLE III. Per cent mortality of corn plants by *H. micacea* following treatments with granular insecticide within 6 days of planting.

Insecticide	Treatment		Mean Per Cent Plant Mortality ¹		
	Rate g a.i./100 m	Band Width	Alma Field	Elora Field	Lancaster Field
Carbofuran	8	15 cm	72.6a	2.6a	29.6a
	16	15 cm	55.0a	5.8a	35.2a
	16	30 cm	71.5a	5.0a	24.7a
Chlorpyrifos	7.4	15 cm	55.9a	5.0a	22.5a
Control			64.6a	4.2a	22.8a

¹ Treatment means within each field are not different ($P < 0.05$).

TABLE IV. Mean per cent mortality of field corn by *H. micacea* following treatment of adjacent fencerow with insecticides.

Insecticide	Rate a.i./ha	Time of Application	Mean Per Cent Plant Mortality ¹		
			Drayton Field	Moorefield Field	Palmerston Field
Cypermethrin	70 g	May 1	20.4 b	14.6 b	23.5ab
		May 7	30.1ab	18.2ab	18.1 b
		May 14	23.6ab	—	—
		May 21	24.2ab	—	—
Control			35.5a	24.5a	28.7a
			Bainsville Field	Lancaster Field	
Permethrin	140 g	May 14	4.0a	6.0 b	
Chlorpyrifos	1.1 kg	May 14	5.6a	5.4 b	
Control		May 14	5.7a	10.5a	

¹ Treatment means within each field followed by the same letter are not different ($P < 0.05$).

damaged plants together with the borers would simulate the effect of an insecticide that would kill a borer but not before the attacked plant was itself killed. That this simulation did not reduce damage indicates that difficulties will be encountered in controlling this pest at the time the corn is being damaged by larvae dispersing from fencerows. Banded treatments of carbofuran or chlorpyrifos as applied for rootworm control were not effective (Table III). However, cypermethrin applied to the fencerows the first week of May, when the larvae were small and before they dispersed into the fields, provided some control on 3 test fields (Table IV). Also, permethrin and chlorpyrifos applied on May 14 reduced subsequent damage in 1 of 2 test fields (Table IV). Unfortunately, single applications of these insecticides reduced plant mortality by less than 54%. Larvae disperse into corn fields from fencerows over a 6-week period (Deedat and Ellis in press). Under these conditions, the prognosis for effective corrective sprays is not good and weed control continues to be emphasized in managing this pest (Ellis, Deedat and Bereza 1982).

Acknowledgments

We thank Mr. B. Beattie for technical assistance. This research was supported in part by the Ontario Ministry of Agriculture and Food.

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THE MORPHOLOGY OF THE STRIDULATORY STRUCTURE OF *HYLURGOPINUS RUFIPES* (COLEOPTERA:SCOLYTIDAE) AND THE USE OF STRIDULATION TO SEX LIVE ADULTS

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Abstract

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The morphology of the stridulatory structures and the distress-related stridulatory behavior of males of *Hylurgopinus rufipes* (Eichhoff) are described. Sexing newly emerged adults on the basis of stridulation movements was 99.5% accurate. For stored adults, sexing by this method was significantly less accurate. Errors in sexing resulted from failure of some males to stridulate and not from stridulation movements in females.

Introduction

The native elm bark beetle, *Hylurgopinus rufipes* (Eichhoff), is one of the two principal vectors in North America of *Ceratocystis ulmi* (Buisman) C. Moreau, the causal fungus of Dutch elm disease. In parts of the range of native elms in Canada and some northerly parts of the United States, *H. rufipes* is the only vector. The seasonal activity of *H. rufipes* (Gardiner 1981) and its role in the transmission of the fungus (Thompson and Matthyse 1972) are well known, but little is known about the behavior of this insect. Lanier (1982) suggested that *H. rufipes* does not produce an aggregating pheromone but mass-colonizes breeding sites in dead or moribund elms in response to host-produced volatiles.

Before behavioral studies on the chemical ecology of *H. rufipes* could be conducted, an accurate method was required for sexing live individuals with minimal handling. Kaston (1936) was unable to find external secondary sexual characteristics in *H. rufipes*, but described structures on the elytra and abdomens of males which indicated that they stridulate. On the basis of Kaston's description, Barr (1969) classified the apparent stridulatory organ of *H. rufipes* as the elytra-abdominal tergites type. Furthermore, stridulation has been used to sex other scolytid species (Chapman 1955; McCambridge 1962, Osgood and Clark 1963; Tate and Bedard 1967). This paper describes the morphology of the stridulatory structures in *H. rufipes* as revealed by scanning electron microscopy and evaluates the utility of stridulation movements as a means of differentiating the sexes in newly emerged adults and after storage under 4 sets of conditions.

Materials and Methods

Adults of *H. rufipes* were obtained from a colony reared at the Great Lakes Forest Research Centre, Sault Ste. Marie (Gardiner and Roden 1977). For scanning electron microscopy (SEM), beetles were killed in 70% ethanol, and sexed by dissection of the genitalia after the elytra and wings were removed. Elytra were mounted on SEM stubs with double-sided sticky tape. Individuals from which the elytra and wings had been removed were transferred to absolute ethanol, dried in a Tousimis Samdri-780® critical-point dryer, and mounted on SEM stubs. Specimens were coated with gold and carbon in a Speedivac® coating unit. Abdomens and elytra were viewed in an AMR model-1000A scanning electron microscope at an accelerating voltage of 10 kV. The elytral file on the left elytron of 10 males and 10 females was photographed and the length (first apical stria to last dense stria), width (100 μ m from apex of elytron), number of ridges, and length of 30 central striae (mid-stria 100 μ m from the apex of elytron) were determined from the micrographs.

For studies of stridulation behavior, adults were collected from rearing containers after the ninth hour of light of a 16-h light: 8-h dark photoperiod. Some beetles were sexed immediately and others after storage under 1 of 4 conditions: 22°C, moist; 22°C, dry; 6°C, moist; and 6°C, dry. Moist storage was with a damp 4 x 2 x 2 cm block of cellulose sponge in the emergence jars. Stored beetles were kept in the emergence jars with partially screened lids for 72 h. Beetles that were held at 6°C were allowed to acclimatize at room temperature for 1 h prior to sexing.

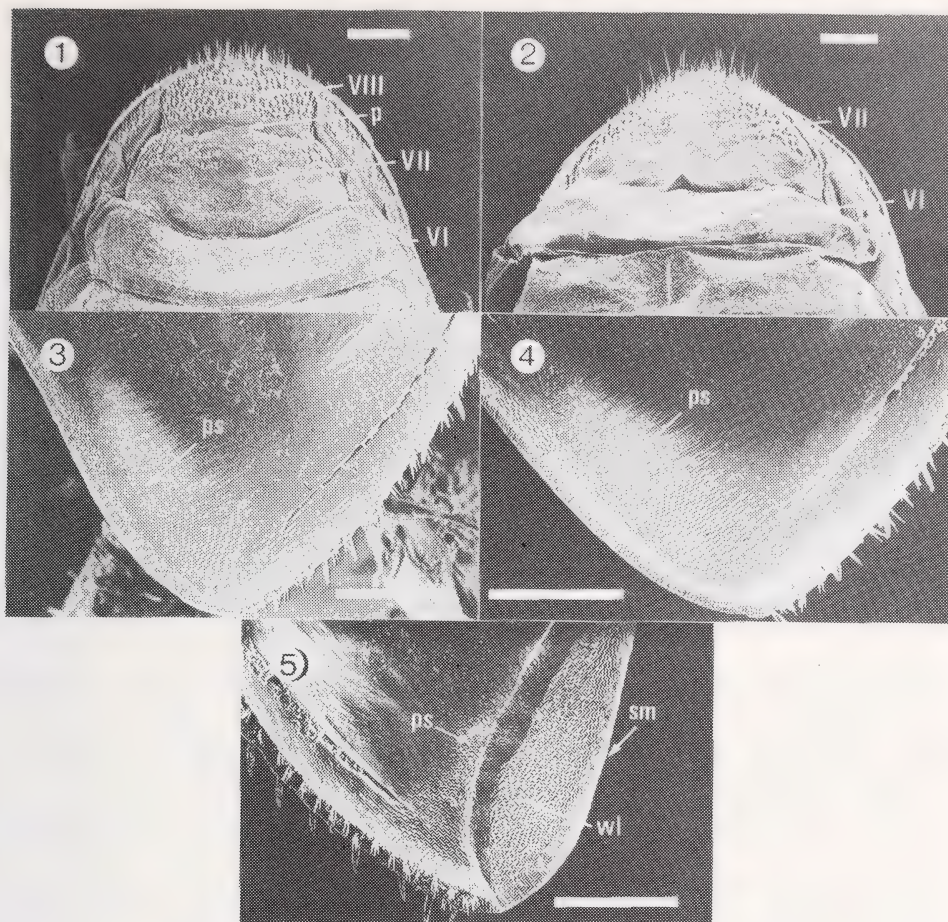
Live beetles were sexed using a dissecting microscope (16X). The beetles were dropped from ca 5 mm above the microscope stage on their dorsa. They were then grasped along the sides of the thorax with soft forceps. If the initial drop or grasping elicited stridulation they were judged to be males. Each beetle was observed for approximately 5 sec. Only active beetles capable of walking were sexed. The beetles of different sexes were placed in separate vials of 70% ethanol. Dead, moribund, or unhealthy beetles, and those damaged in handling, were placed in a third vial. Collections from the rearing containers were continued until each treatment had a sample size of over 500 beetles. All beetles included in a 24-h emergence sample were sexed. Initially sex was verified by dissection of the genitalia, but later was confirmed by removal of the abdomen and viewing of the abdominal tergites under a dissecting microscope (16X).

Results and Discussion

From the dorsal view, the abdomens of males and females of *H. rufipes* were distinct (Fig. 1-2). The seventh and eighth tergites of males were visible while the eighth tergites or pygidia of females were concealed beneath the seventh tergites. The posterior margins of the seventh tergites were rounded in females but the males possessed bifid processes that serve as the stridulatory scrapers or plectra. When observed under a dissecting microscope the posterior margin of the seventh tergite of the male has a heavily sclerotized band. Kaston (1936) described and schematically diagrammed these structures on the basis of light microscopic examinations but suggested that the process on the male was not well adapted for scraping against the pars striden or stridulatory file. However, the described structures are typical of scolytids possessing the 'elytral-abdominal tergites' type of stridulatory organ such as described for *Dendroctonus* spp. (Michael and Rudinsky 1972, Rudinsky and Michael 1973), *Leperisinus* spp. (Vernoff and Rudinski 1980), and *Hylurgops* sp. (Barr 1969).

The pars stridens of *H. rufipes* (Fig. 3-4) consisted of a series of parallel ridges traversing the underside of the apex of the left elytron adjacent to the sutural margin. Kaston (1936) stated that the structure on the elytron was the same in both sexes. However, measurements of the pars stridens (Table I) indicated that on males the file is significantly longer than on females and has a significantly greater number of ridges. This study showed that the ranges of the lengths of male and female files overlap slightly whereas the number of ridges do not. The differences in pars striden morphology of males and females are similar to those of other scolytids mentioned previously. As described by Kaston, the ridge density is greatest at the anterior end and the striae are longest at the apex of the elytron. There is evidence of striae on the right elytron (Fig. 5) adjacent to the winglock; these are continuous with those on the left elytron when at rest.

The stridulatory behavior in the male, when viewed ventrally, consists of a dorsoventral twitching or high-frequency vibration of the apex of the abdomen in a motion that would draw the plectrum across the stationary pars stridens. The abdomen articulates between the third and fourth caudal sternites. The sound produced was audible when the beetle was placed close to the listener's ear. This sound is similar to the "stress chirps" described by Michael and Rudinsky (1972) in *Dendroctonus* spp. As in



FIGS. 1-5. Scanning electron micrographs of the stridulatory structure of *Hylurgopinus rufipes*. 1, dorsal view of caudal segments of male abdomen. 2, dorsal view of caudal segments of female abdomen. 3, apical tip of underside of left elytron of male. 4, apical tip of underside of left elytron of female. 5, apical tip of underside of right elytron of male. Abbreviations: p, plectrum; ps, pars stridens; sm, sutural margin; wl, winglock area; VI, sixth tergite; VII, seventh tergite; VIII, eighth tergite. horizontal bar = 100 μ m.

other species of Scolytidae (Oester *et al.* 1981), stridulation in *H. rufipes* is probably multifunctional.

The sex ratio of the beetles studied approximated unity (Table II). Sexual determination of newly emerged beetles by stridulation movements was 99.5% accurate. This result was far more accurate than that achieved by Osgood and Clark (1963) when they sexed a small sample of *D. frontalis* by stridulation sounds. The technique was significantly less accurate after adults were stored. Many beetles stored at 22°C without moisture died. The low accuracy for sexing this group was because some males were too weak to stridulate. Beetles held at 6°C with moisture provided by the damp sponges probably had not fully warmed to room temperature when sexed. Chapman (1955) reported that this sexing technique did not work for abnormal or weak males of *D. pseudotsugae* or for

TABLE I. Morphology of the pars stridens of *Hylurgopinus rufipes*.

Sex	Length (μm)	Width (μm)	Length of 30 striae (μm)	Number of ridges
♂	230 $\pm$ 7.3 ^a (218 - 240)	75 $\pm$ 14.5 (58 - 99)	56 $\pm$ 7.9 (41 - 71)	147 $\pm$ 16.7 (118 - 174)
♀	185 $\pm$ 22.1 (143 - 218)	68 $\pm$ 7.9 (56 - 85)	51 $\pm$ 11.4 (38 - 73)	96 $\pm$ 7.3 (84 - 108)
	*	n.s.	n.s.	*

^amean $\pm$ S.D.; (range)

* $p < 0.001$ (Student's *t*-test)

n.s. = not significant

TABLE II. Accuracy of sexing *Hylurgopinus rufipes* by stridulation movement

	0-24 h after emergence	3-4 d after emergence				Totals
		6°C		22°C		
		moist	dry	moist	dry	
♂♂ stridulation	285	246	273	213	70	1087
♀♀ stridulation	0	1	0	0	0	1
♂♂ no stridulation	3	22	10	14	62	111
♀♀ no stridulation	270	242	267	256	146	1181
♂♂ dead or unhealthy	0	6	7	19	114	146
♀♀ dead or unhealthy	0	10	8	22	111	151
Total	558	527	565	524	503	2677
Sex ratio (♂♂ / ♀♀)	1.07	1.08	1.05	0.88	0.95	1.01
% error (excluding dead or unhealthy)	0.5a*	4.5c	1.8b	3.0bc	23.1d	4.9
% dead or unhealthy	0a	3.0b	2.7b	7.8c	44.5d	11.1

*Number in the same row followed by different letters are significantly different (χ^2 -square, $p \leq 0.05$).

those inactivated by cold. The presence of heavy infestations of parasitic and phoretic mites on some adults of *H. rufipes* and the presence of teneral adults had no effect on the sexing technique.

Tate and Bedard (1967) found that sexing *D. brevicornis* by stridulation sound and movement was inaccurate because some males did not stridulate and some females produced stridulation-like movements. Although Chapman (1955) sexed *D. pseudotsugae* fairly reliably by stridulation sounds, he reported that females made repeated movements of the abdominal segments that could only be differentiated from male stridulation movements by their lower frequency. In all the current tests only one female *H. rufipes* was misidentified as a male. This could well have resulted from a handling error rather than from stridulation-like behavior of the insect. Unlike females of *D. pseudotsugae*, females of *H. rufipes* did not move their abdomens when held in the position described. The results reported here are similar to those of McCambridge (1962)

who found that sexing *D. ponderosae* by inducing stridulatory movements was 96% accurate; females did not produce stridulation-like movements when held in the appropriate manner. Testing each individual more than once should increase further the accuracy of sexing females, but result in excess handling and possible damage to the beetles.

Acknowledgments

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DIEL BITING ACTIVITY OF *MANSONIA PERTURBANS*¹ (DIPTERA: CULICIDAE) IN SOUTHWESTERN ONTARIO

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Abstract

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Diel biting activity of *Mansonia perturbans* was examined in southwestern Ontario during 1977 and 1978. Activity during early summer (30 June, 7 and 13 July) and late summer (9, 16 and 24 August) was crepuscular with one peak before sunrise (0300-0500 h EST) and one after sunset (1900-2100 h). Diel periodicity was more pronounced in the early summer when greatest activity occurred. Biting activity was greatest ca. 75 min. after sunset and 60 min. before sunrise. Observed biting activity was rarely modified by environmental conditions of wind speed, rainfall, temperature and relative humidity.

Introduction

Mansonia perturbans (Walker) is a major nuisance mosquito in areas of freshwater marshes throughout eastern North America, including southern Ontario (Wood *et al.* 1979). Isolations of arboviruses from this species, such as Eastern Equine encephalitis in New York (Srihongse *et al.* 1978), Western Equine encephalitis in Manitoba (Sekla *et al.* 1980) and California encephalitis (Snowshoe hare) in Ohio (Parsons and Berry 1978), indicate its potential significance in regard to human health.

Investigations of diel biting activity of medically important insects are important for epidemiological studies of the disease, and control considerations. Discrepancy currently exists among reports on the diurnal pattern of biting activity of this species. Several researchers have indicated that peak biting activity occurs only at dusk (McNeel 1932, Gladney and Turner 1969, Taylor *et al.* 1979, Lewis and Bennett 1980), whereas, Snow and Pickard (1957) reported that biting activity peaks at both dawn and dusk. Gladney and Turner (1969) observed no activity during daylight hours, whereas, Taylor *et al.* (1979) collected one-third of their specimens during daylight hours. Discrepancy also exists concerning the time of maximum biting activity related to the time of sunset (Taylor *et al.* 1979, Lewis and Bennett 1980). This study was undertaken to determine a) the pattern of biting activity throughout 24-hr periods, b) the biting activity during dawn and dusk, c) to determine if a change in the periodicity of biting activity occurred within a season.

Materials and Methods

Studies were conducted at two Ontario sites described by Allan *et al.* (1981) adjacent to large freshwater marshes; one at St. Catharines (43° 10' N, 79° 20' W) and the other at Pt. Pelee (41° 59' N, 82° 38' W). Biting collections consisted of all mosquitoes landing and probing on one forearm of each of the two collectors during a 15-min. period. Mosquitoes were collected by means of an aspirator and placed in test tubes stoppered with cotton. The same two individuals made all of the collections, to ensure uniformity of attraction and technique. The data are presented as the mean number of *M. perturbans* per person in each 15-min. interval. The biting collections were conducted ca. 4 m from the edge of the marsh. Vegetation within 1 m of the site and along the path to the site, which was used for the entire season, was cleared to prevent increased activity of mosquitoes by movement of the collector. Biting collections commenced at least 15 minutes after movement of the collector into the area.

¹Taxonomic status as per Wood *et al.* (1979).

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Diel biting activity was measured during six 24-hr periods at Pt. Pelee in 1978. Biting collections were conducted on 30 June, 7 and 13 July and on 9, 16 and 24 August to determine if a seasonal change in diel periodicity of biting activity occurred similar to that of *Culiseta inornata* (Williston) (Barnard and Mulla 1977). Mosquitoes were collected during a 15-minute period at the beginning of every hour throughout the 24-hr period. As mosquitoes are neither attracted nor repelled by a red light (Clements 1963), a flashlight with the lens covered by a red filter was used to illuminate the forearm of the collector during collection periods which occurred after sunset.

The time of sunrise and sunset for collections was calculated from the Observer's Handbook 1977 (Percy 1977). Preceding each biting collection, air temperature, barometric pressure, wind velocity and relative humidity were recorded. Daily records of precipitation and maximum and minimum temperatures were obtained from nearby meteorological stations. Wind velocity was measured 1.5 m above the ground by a hand-held anemometer (Dwyer Instruments Inc.) and relative humidity measured by a sling psychrometer (Casella®). From 7 June until 7 September 1977, biting activity at dusk was evaluated from collections that were made once a week from ca. 1830 to 2130 h (EST) at Pt. Pelee and at 1900 to 2100 h (EST) at St. Catharines. From 30 June until 3 September in 1978, biting activity at dawn was evaluated at Pt. Pelee from weekly collections made from 0300 to 0700 h (EST). The time of sunrise and sunset varied by at least one hour during the collecting season. To compensate for these changes, and to allow valid comparison of collections between days, collections were timed around sunrise or sunset. Thus, mosquitoes were collected during successive 15-minute intervals timed such that one collection period would begin at sunrise or sunset.

Data from biting collections made at dawn and dusk were expressed using "William's Mean" (Haddow 1960) to reduce bias of a large value resulting from unusual weather conditions. William's mean is defined by

$$\log (M_w + 1) = \frac{\log (n + 1)}{N}$$

where $n_1, n_2, \dots$ represent actual values of a series of N observations. Values used in Fig. 2 are actual numbers converted from the above calculation.

Results and Discussions

Diel Periodicity. A total of 4621 females of *M. perturbans* were collected, 1185 from six 24-hr collections, and 3436 from 13 dawn and dusk collections. No males were observed during collections.

Diel periodicity of biting activity during early and late summer is presented in Fig. 1. The time of sunrise and sunset varied 4 minutes from 30 June to 13 July and 20 minutes from 9 to 24 August. The mean time of sunrise and sunset is indicated in Fig. 1. Throughout the 24-hr period, two distinct peaks of activity were seen; one occurred before sunrise (0300-0500) and one after sunset (1900-2100). Throughout the remainder of the day, a low level of biting activity occurred. This activity pattern has been described as 'eo-crepuscular' (Haddow 1945) and is similar to those of *Anopheles freeborni* Aitken (Nelson and Spadoni 1972) and *Aedes sollicitans* (Walker) (Ebsary and Crans 1977).

The majority of adults were present during early summer (Allan *et al.* 1981) and the peaks of activity were well defined. During late summer, fewer adults were present and peaks were less pronounced. In early summer, 39.3% of the biting activity of the day occurred from 0300-0500 h, and 32.6% occurred from 1900-2100 h. In late summer, 19.4% occurred from 0300-0500 h, and 32.9% occurred from 1900-2100 h.

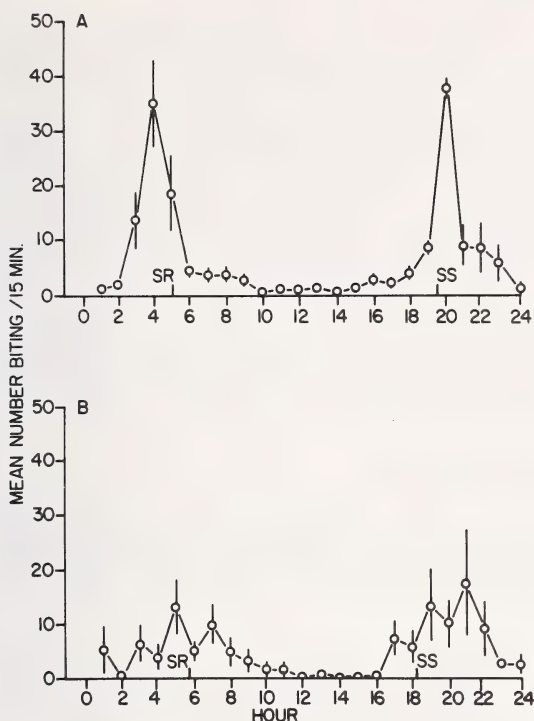


FIG. 1. Diel periodicity of biting activity of *Mansonia perturbans* at Pt. Pelee, Ont. A, 30 June, 7 and 13 July 1978; B, 9, 16 and 24 August 1978. Bars represent standard error of the mean. SR = sunrise, SS = sunset.

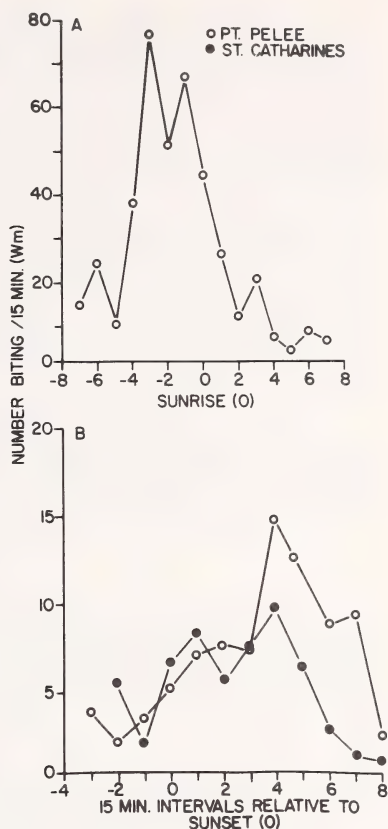


FIG. 2. Biting activity of *Mansonia perturbans* at dawn or dusk at St. Catharines and Pt. Pelee, Ont. during June and July 1977. (Wm = William's mean).

In Alabama, Snow and Pickard (1957) found that adults of *Mansonia perturbans* fed predominantly during the hour after sunset and before sunrise. At sunset, mosquitoes moved into the forest canopy or to grasslands to feed and returned to the forest at dawn. After the peak biting period, mosquitoes would rest on nearby vegetation, then fly away, rarely attempting to feed on collectors. Direction of movement could not be detected. During mid day and the middle of the night, low levels of biting activity (3% of the daily total) occurred. This was contrary to a report by Gladney and Turner (1969) that no flight activity was seen during the day, but agreed with Taylor *et al.* (1979) and Lewis and Bennett (1980).

Activity During Dusk and Dawn. Activity at dawn at Pt. Pelee in 1978 (Fig. 2A) increased 75 minutes to 30 minutes before sunrise. Fifty-seven per cent of the biting activity from 0300 to 0700 hours occurred within 60 minutes before sunrise. This agreed with observations by Snow and Pickard (1957) that activity at dawn increased from 30 minutes before they could measure light and declined when light intensity exceeded 21.5 lux.

Biting activity of *M. perturbans* at dusk at St. Catharines and Pt. Pelee in 1977 (Fig. 2B) increased one hour after sunset. Fifty-one per cent of the biting activity occurred

between 1900 and 2100 hours at St. Catharines and 51.6% of the biting activity occurred between 1830 and 2130 at Pt. Pelee. In Alabama, 88.9% of the biting activity was observed from 1700 to 1900 h (Snow and Pickard 1957).

Observation on Environmental Factors Affecting Activity. Temperatures during biting counts ranged from 17 to 26° C in 1977 and 12 to 26° C in 1978. Winds were generally under 3 kmph, with occasional gusts up to 16 kmph. Barometric pressure ranged from 748-757 mm Hg and relative humidity varied from 74 to 100%. Qualitatively, temperature, wind velocity, relative humidity, and barometric pressure did not appear to affect activity. These observations agree with those of Taylor *et al.* (1979). Two exceptions were an unexpected increase in collection immediately after a light rainfall at 2205 h at St. Catharines on 25 July 1977, and after moderate gusting winds (33 kmph) lasting for 1.5 hours on 9 August 1977 at Pt. Pelee. The temperature of 12° C occurred on 24 August 1978 and the effect on mosquito collections was difficult to assess due to the low populations at that time.

Larval control of *M. perturbans* is generally considered impractical since larvae are attached to cattail roots. Control, by necessity, must be through use of adulticides. This study indicates that the optimal time for adulticiding programs is within two hours after sunset and one hour before dawn.

Acknowledgments

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EFFECTIVENESS OF MALATHION AND PIRIMIPHOS-METHYL
APPLIED TO PLYWOOD AND CONCRETE TO CONTROL
PROSTEPHANUS TRUNCATUS (COLEOPTERA: BOSTRICHIDAE)¹

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Abstract

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Malathion and pirimiphos-methyl were applied to plywood at concentrations of 0.125, 0.250, 0.375, and 0.500 g a.i. (active ingredient)/m² to determine their effectiveness in controlling adults of the larger grain borer, *Prostephanus truncatus* (Horn). The plywood was stored at 21°C and was bioassayed over a period of 16 weeks. Concrete blocks were sub-divided into two parts and one section was covered with a thin layer of corn dust. Both dust-free and dust-covered concrete were treated with malathion or pirimiphos-methyl at 0.5, 1.0, and 2.0 g a.i./m². The concrete was stored at 21°C and was bioassayed with *P. truncatus* over a period of 8 weeks. Residual toxicity of both insecticides was greater on dust-covered concrete than on dust-free concrete. Malathion was less effective than pirimiphos-methyl as a residual insecticide for control of *P. truncatus*, notably on concrete although differences in mortality caused by the insecticides on plywood were not great.

Introduction

The larger grain borer, *Prostephanus truncatus* (Horn) is a destructive pest of field and stored corn in Central America and Mexico (Ramirez 1960) and has been found in the southern U.S. (Hodges 1982). It is also a potential pest of corn in temperate zones of North America (Bell and Watters 1982), including southern Ontario. Recently this insect was found attacking stored corn cobs, cassava, peanuts, and boring into wooden storage structures in Tanzania. In response to the spread of this insect, the Food and Agricultural Organization of the United Nations has recommended that control methods for this insect include shelling the corn and mixing 10 ppm pirimiphos-methyl with the kernels (Anon. 1981).

P. truncatus is unable to breed successfully on crops other than corn (Shires 1977) and breeds poorly on shelled corn preferring to bore into kernels from inside the cob (Bell and Watters 1982). This behavior of boring through the cob makes *P. truncatus* difficult to control after infestation. Eliminating populations of this insect in empty storage structures or vehicles used for transportation is an important aspect of effective control.

The persistence of insecticide residues depends, in part, on the substrate (Mensah and Watters 1981) and the persistence indicates when reapplication is necessary. Since malathion is inexpensive, is readily available in North America, and is currently the main insecticide registered for admixture with stored products in Canada, the relative effectiveness of malathion and pirimiphos-methyl for control of *P. truncatus* needed to be investigated. The aim of this study, therefore, was to compare malathion and pirimiphos-methyl, applied to plywood and concrete surfaces similar to those found in storage structures, for residual toxicity to *P. truncatus*.

Materials and Methods

Malathion, 83.6% EC, and pirimiphos-methyl, 84.0% EC, were applied to plywood

¹Contribution No. 1064 from the Agricultural Canada Research Station, 195 Dafoe Road, Winnipeg, Manitoba, Canada, R3T 2M9.

and concrete blocks. The treated materials were stored in the dark at $21 \pm 2^\circ\text{C}$ and $30 \pm 5\%$ RH and bioassayed periodically in the storage environment with *P. truncatus* reared at $30 \pm 1^\circ\text{C}$ and $70 \pm 5\%$ RH on whole-corn kernels. Insects were confined for 24 h on the treated surface inside copper cylinders, 5.0 cm diam x 2.1 cm high, which had been coated with Fluon (polytetrafluoroethylene) to prevent the insects from crawling out. A fine screen cover over each cylinder prevented escape by flying. After 24 h the beetles knocked down, or unable to walk, were counted. The insects from each cylinder were then placed in glass vials, 1.25 cm diam x 3.0 cm high, containing about 3 g of ground field corn, cv. "Pioneer 3993". Following a 3- to 5-day recovery period at $30 \pm 1^\circ\text{C}$, $70 \pm 5\%$ RH, living and dead insects were counted after removing them from the corn. Insects were scored as dead if they failed to respond to prodding with a fine sable-hair brush.

Plywood treatments. The insecticides were diluted with water to 0.25, 0.50, 0.75, and 1.0% solutions and applied to fir plywood panels to give deposits of 0.125, 0.250, 0.375, and 0.500 g a.i. (active ingredient)/ m^2 . Two hundred and sixteen plywood panels, 13 x 13 x 0.6 cm, were sprayed using a Paasche air brush with a No. 5 nozzle at 69 KPa pressure. The 4 dosages of malathion, 4 dosages of pirimiphos-methyl, and a water check were each applied to 24 panels. Four panels from each insecticide-dose combination and the controls were bioassayed with adult *P. truncatus* after 1 day, 1, 4, 8, 12, and 16 weeks. Two copper cylinders, each containing 20 insects, were used per panel, 8 replicates per treatment; 1440 insects were used on each bioassay date.

Concrete treatments. Each of 14 concrete blocks, 40 x 20 x 3 cm, was marked in one-half with a piece of masking tape. The surface of one-half of each block, 20 x 20 cm, was covered with corn dust screened to pass through 20-mesh openings (0.85 mm aperture). The dust was ground into the surface for 1 minute with a small square of plywood. Loose dust was then shaken off the block and the procedure repeated 3 times to fill the surface pores. Each of the following dosages of malathion or pirimiphos-methyl was then applied to 2 blocks as previously outlined: 0, 0.5, 1.0, and 2.0 g a.i./ m^2 . The blocks were bioassayed with adult *P. truncatus* after 1 day, 1, 4, and 8 weeks. Different areas of the blocks were bioassayed on each sampling date; 2 replicates of 20 insects were exposed to each half of every block; 1120 insects were used on each bioassay date.

Statistical Analyses. Treatment mortalities were adjusted for mortality in the controls by Abbott's formula and were transformed to logits. The University of California BMDP1R program (Dixon and Brown 1979) was used to calculate regressions of mortality on weeks in storage. Regression coefficients and variance of the coefficients were analyzed using a t-test for multiple pairwise comparisons accommodating unequal variances and the relative response of the treatments compared (Snedecor and Cochran 1971).

Results and Discussion

Plywood treatment. Mortality in the controls never exceeded 3% on the plywood treatment. Knock-down by both insecticides on all surfaces was up to 10% higher than final mortality but there was generally a good correspondence between knock-down and mortality.

Pirimiphos-methyl applied at 0.125, 0.250, 0.375 g a.i./ m^2 initially produced greater ($P < 0.01$) mortality than malathion at corresponding dosages within 24 h of application (Fig. 1). However, the mean mortalities caused by each insecticide over 16 weeks were approximately similar. Malathion applied at the recommended rate for structural treatments (Watters 1976), 0.500 g a.i./ m^2 , resulted in mortalities $> 90\%$ for 16 weeks while mortality caused by pirimiphos-methyl fell to 50% by 12 weeks. This anomaly may have been caused by uneven coverage of the panels in this treatment since lower concentrations resulted in higher mortality. Both insecticides resulted in $> 85\%$

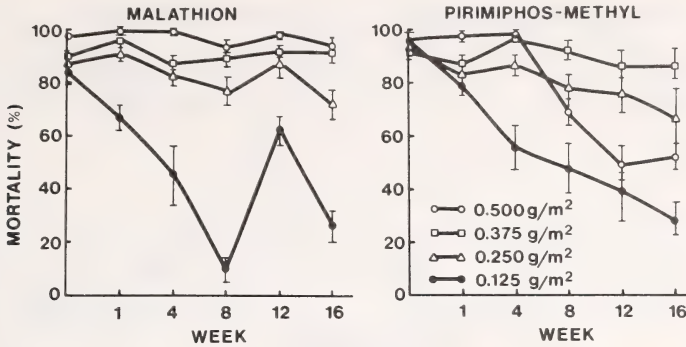


FIG. 1. Percent mortality (mean $\pm$ standard error) of *Prostephanus truncatus* adults exposed to malathion and pirimiphos-methyl residues on plywood stored at 21°C and 30% RH.

mortality over a 16-week period when applied at 0.375 g a.i./m². Pirimiphos-methyl was more effective than malathion for the control of *P. truncatus* when applied to plywood, especially at 0.125 g a.i./m² over 8 weeks. The increase in mortality in the malathion treatment at week 12 may have been the result of uneven spray coverage of the panels.

LaHue (1977) indicated that pirimiphos-methyl applied to seed corn was more effective than malathion for control of several species of stored-product beetles and moths. The residual toxicity to *Rhyzopertha dominica* (F.) of pirimiphos-methyl applied at 7.8 ppm was similar to that of malathion applied at 10.4 ppm on wheat (LaHue and Dicke 1977). These observations indicate that pirimiphos-methyl was more effective than malathion in controlling stored-product beetles in grain; pirimiphos-methyl also had longer residual activity in cereal kernels (Mensah *et al.* 1979). Over a 16-week period, the significant differences in mortality caused by the 2 insecticides, when applied to plywood as residual sprays, were probably not biologically important.

Concrete treatment. Malathion applied at 0.500 g a.i./m² resulted in greater ($P < 0.01$) mortality of *P. truncatus* on dust-covered than on dust-free concrete (Fig. 2). There was no difference ($P > 0.05$) between mortalities when pirimiphos-methyl was applied to dust-covered, or dust-free concrete at 0.500 g a.i./m². Pirimiphos-methyl applied at 0.500 g a.i./m² on both dust-covered and dust-free concrete produced greater ($P < 0.01$) mortality than malathion applied at the same dose on dust-free concrete. There was no difference ($P > 0.05$) in mortality on dust-free concrete treated with 1.0 g a.i./m² of pirimiphos-methyl or malathion, or dust-treated concrete at the same dosage of malathion. Mortalities on dust-covered concrete at 1.0 g a.i./m² of pirimiphos-methyl were greater ($P < 0.01$) than on the other surfaces treated with both chemicals at the same dose.

Malathion applied at 2.0 g a.i./m² caused greater ($P < 0.01$) mortality on dust-covered concrete than on dust-free concrete. Pirimiphos-methyl applied at 2.0 g a.i./m² on dust-covered concrete resulted in greater mortality ($P < 0.01$) than on dust-free concrete, or than malathion on dust-free concrete at the same dose.

Malathion applied at 1.0 or 2.0 g a.i./m² to dust-free concrete resulted in $> 90\%$ mortality of *P. truncatus* within 1 day only. Malathion at 0.5 g a.i./m² caused mortalities of 46% after 1 day declining to 15% after 1 week. This insecticide at 0.5 g a.i./m² caused 84% mortality after 1 day. Mortality declined to 20% after 1 week on dust-covered concrete.

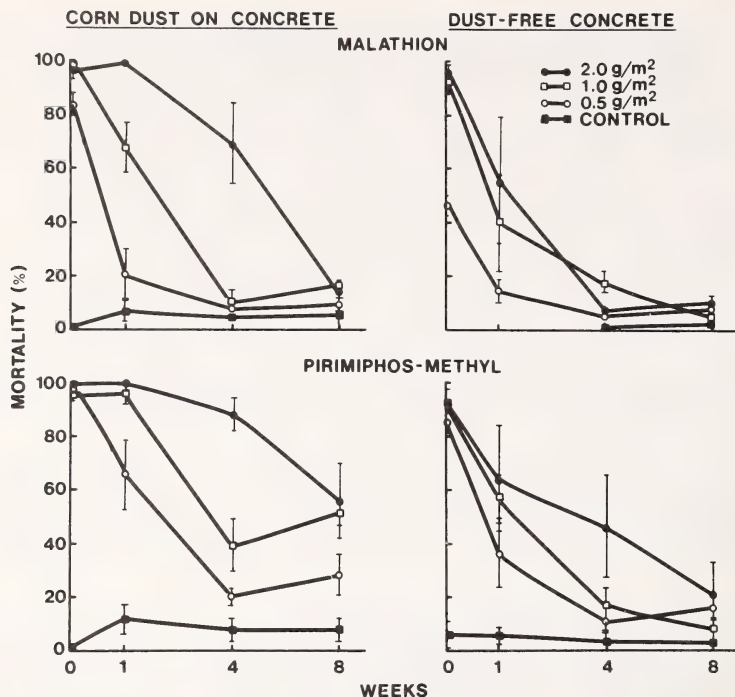


FIG. 2. Percent mortality (mean $\pm$ standard error) of *Prostephanus truncatus* adults exposed to malathion or pirimiphos-methyl residues on corn-dust-covered or dust-free concrete stored at 21°C and 30% RH.

Pirimiphos-methyl applied at rates of 1.0 and 2.0 g a.i./m² to dust-free concrete resulted in $>90\%$ mortality of *P. truncatus* after 1 day. Mortality at 0.5 g a.i./m² was 85% at 1 day and 36% at 1 week. Mortalities of 96% after 1 day and 66% after 1 week resulted when pirimiphos-methyl was applied at 0.5 g a.i./m² to dust-covered concrete.

Mortality on concrete caused by pirimiphos-methyl was greater than that caused by malathion at similar doses. The presence of corn dust increased the residual toxicity of both chemicals, especially pirimiphos-methyl which resulted in greater mortality than malathion at similar dosages. At 8 weeks after treatment the mortality of *P. truncatus* was above 50% only on dust-covered concrete sprayed with 1.0 or 2.0 g a.i./m² of pirimiphos-methyl.

The alkaline pH of concrete surfaces results in the rapid breakdown of many insecticides, especially malathion (Okwelogu 1968). The application of corn dust to the concrete simulated realistic surface conditions where dust is present on floors, probably lowering the pH of the surface and decreasing its porosity or surface area. Therefore, the present results are likely to be valid in practical storage situations.

Comparison of malathion and pirimiphos-methyl. Malathion was less effective as a residual insecticide than pirimiphos-methyl for the control of *P. truncatus*. However, mean mortality caused by both insecticides applied to plywood was similar. Both insecticides resulted in effective control of *P. truncatus* adults for 16 weeks when applied to plywood at 0.375 g a.i./m². Pirimiphos-methyl was more effective than malathion when applied to concrete and the residual action of both insecticides increased on concrete covered with corn dust.

Malathion and pirimiphos-methyl provided approximately equivalent control of *P. truncatus* when used as residual treatments on the structural materials tested, especially plywood. Since malathion resistance has not been observed in this insect, the low cost and availability of this insecticide makes malathion the insecticide of choice in North America.

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COTESIA (APANTELES) RUBECULA (HYMENOPTERA: BRACONIDAE)
RECOVERED IN OTTAWA, ONTARIO
TEN YEARS AFTER ITS RELEASE

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Cotesia (= *Apanteles*) *rubecula* (Marsh.), a solitary, braconid parasite, was introduced into eastern Canada in 1970 and 1971 as a biological control agent of the imported cabbageworm, *Pieris rapae* (L.). Adult *C. rubecula* were released by Dr. D. G. Harcourt, Agriculture Canada, Ottawa, from a culture reared in the Biological Control of Insects Laboratory at Columbia, Missouri. This culture was started from individuals collected in southern British Columbia where *C. rubecula* was first found in North America (Wilkinson 1966). Harcourt released 1,183 individuals in 1970 (Williamson 1971), and 309 individual in 1971 (Williamson 1972) at Richmond, Ontario, about 30 km southwest of Ottawa. The parasite was not recovered in the next decade.

On July 2, 1982, four cocoons of *Cotesia* were found on four small cabbage plants in a back yard garden in Ottawa South. Adult female *C. rubecula* emerged from 2 of the cocoons; *Tetrastichus* sp. (Eulophidae), a gregarious wasp, emerged from one cocoon and nothing emerged from the fourth cocoon.

Adults of *C. rubecula* from British Columbia were released in southern Ontario, near Guelph, and at the Agriculture Canada Research Station, Harrow in 1978 and 1979. A total of 585 *C. rubecula* adults (250 ♀ ♀, 295 ♂ ♂, 40 sex not determined) were released into cultivated cabbage plots in the Guelph area and 180 ♀ ♀ and 120 ♂ ♂ were released at Harrow (Jaques and Laing, in press). *C. rubecula* were recovered in the Guelph plot in both years of release after two generations, however, no parasites have been found in either Guelph or Harrow in subsequent years.

The recovery of individuals of *C. rubecula* in a small suburban garden in Ottawa more than 10 years after release and approximately 30 km from the original release site indicates that the parasite has become established in the area. Releases in the Guelph area have not resulted in recovery of parasites in the year after release, i.e. after a winter cold period, but the discovery of *C. rubecula* in Ottawa shows that the parasite can overwinter in Ontario. The release of parasites with greater winter hardiness, and the preservation of release plots without cultivation until spring, should aid in permanently establishing *C. rubecula* in southern Ontario.

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TECHNIQUES FOR COLLECTING AND HANDLING SMALL DIPTERA

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Some of the problems commonly encountered by students of small Diptera include the health hazards of aspirating flies from some substrates, difficulties in storing and transporting specimens on field trips, low numbers of some families in Malaise traps, and storage of large samples in the laboratory. Some solutions to these problems are suggested below.

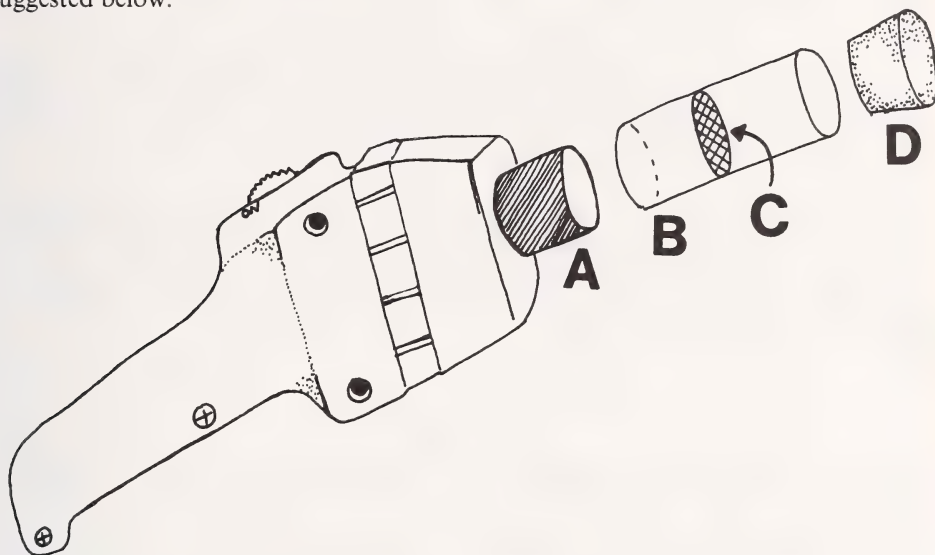


FIG. 1. Vacuum aspirator made from a Black and Decker rechargeable Dustbuster™ vacuum cleaner. A, plastic tube mounted over fan housing; B, plexiglass collecting chamber; C, screen barrier; D, no. 7 rubber stopper.

Aspirating from objectionable or dangerous substrates. Direct aspiration from dung, from carrion, from fungi, or in caves can be hazardous, and aspirating from other substrates can result in allergic reactions. Blow-through (venturi) aspirators usually lack sufficient suction, and power operated vacuum aspirators of which published descriptions are available (i.e. Weekman and Ball 1963) are inconveniently bulky or heavy. These problems can be overcome by using a small vacuum aspirator made from a portable automobile vacuum cleaner. The rechargeable models made by Black and Decker are excellent for this purpose. Detachable aspirator heads can be made from 32-mm (inside diameter) plexiglass tubing (Fig. 1). A screen barrier (Fig. 1) can be glued into the plexiglass tube, or held in place using a plastic ring cut from a standard 35-mm film container. These aspirator heads fit directly over the end of the old model Black and Decker auto vacuum, but the newer and more powerful DustBuster™ must be modified as in Figure 1. The dust chamber is discarded and a small tube, made from a standard 35-mm film container, is affixed, using molten plastic or hot glue, directly over the fan input hole. A tool which melts sticks of plastic for adhesive purposes is widely available and marketed under the name 'hot glue gun'. The same adhesive is also used to seal the space surrounding the small tube. Aspirator heads can then be snapped on and off this

tube. The vacuum aspirator is excellent for emptying light traps and car nets, and is well suited for collecting live samples from different microhabitats.

Field storage and transport. Specimens transported in vials of alcohol, either on extended field trips or in the mails, are subject to damage by jostling. Also, the weight and bulk can be inconvenient. A large number of samples can be stored in alcohol in fine mesh bags placed in a single plastic bottle. This does not damage the fine structures used in chaetotaxy and greatly reduces weight and volume. Contents of pan traps and pitfall traps can be poured directly into mesh bags, but these should then be rinsed in water before storage in alcohol. Mesh bags can be used with the vacuum aspirator described above by inserting a bag directly into the end of the collecting chamber and aspirating specimens directly into the bag.

Poor catches in Malaise traps. Many small insects, especially sphaerocerid flies, rarely move to the apex of a Malaise trap and thus, are not captured. During a season-long study of supralittoral Diptera (Marshall 1979), pan traps placed under the barrier panel of a Malaise trap collected larger numbers of Diptera than either the trap-head collecting device of the Malaise trap or pans placed away from the Malaise trap.

Preparation and storage of lab material. At the University of Guelph, a simple large-capacity critical-point drier is used to dry insects which have been preserved in alcohol. Once dry, material does not shrivel and retains limited flexibility for a long time. Dried samples are placed in small snap-top petri dishes which are then stored on wooden trays. This allows ready access to a large collection of dried specimens in good condition for mounting and labelling as required.

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THE SOCIETY

PRESIDENT'S PRIZE — 1983

Richard M. Fisher was the President's Prize recipient at the annual meeting in Guelph in October, 1983. He presented a paper entitled "Dominance of host workers by two species of bumble bee social parasites". Mr. Fisher received his BSc from Trent University in 1979. Since that time, he has conducted doctoral research, at the University of Toronto, dealing with the ecology and evolution of brood parasitism in bumble bees. He believes that there are unifying themes which can be used to explain the occurrence of occasional (facultative) and obligate nest usurpation in many groups (e.g. birds, bees and wasps). Providing there are ways in which an individual can force or coerce a potential host into rearing its young, there are distinct advantages in usurping the reproductive efforts of others. The most important of these are not having to incur risks in starting a nest, and avoiding the heavy mortality which occurs in young nests.

A NEW INTERNATIONAL AWARD

The Council for the International Congresses of Entomology recently approved a new "Distinguished International Award in Morphology and Embryology", to be presented to an outstanding morphologist or embryologist at each future Congress of Entomology.

Two awards will be presented at the next Congress in Vancouver, Canada: one retroactively for 1984 and the other for 1988. Full details of the selection procedures will be published in the December 1984 issue of the *International Journal of Insect Morphology & Embryology* and subsequently in other journals. For additional information regarding this award, one may call (201 - 932 - 9873/9459) or write to A.P. Gupta, Editor-in-Chief, *International Journal of Insect Morphology & Embryology*, Department of Entomology & Economic Zoology, Rutgers University, New Brunswick, NJ 08903, U.S.A.

**COMPETITION BETWEEN
DIADEGMA INSULARE (HYMENOPTERA: ICHNEUMONIDAE) AND
MICROPLITIS PLUTELLAE (HYMENOPTERA: BRACONIDAE)
FOR LARVAE OF THE DIAMONDBACK MOTH, *PLUTELLA XYLOSTELLA*
(LEPIDOPTERA: PLUTELLIDAE)**

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Abstract

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Competition between *Diadegma insulare* (Cress.) and *Microplitis plutellae* Muesbeck for their host *Plutella xylostella* (L.) was assessed. *D. insulare* produced an average of 814 eggs per female whereas *M. plutellae* produced an average of 316 eggs per female at 23°C. The development of both parasites was highly synchronized with the development of the host. *D. insulare* required 282 degree-days above 6.6°C and *M. plutellae*, 218 degree-days above 9.2°C to develop from egg to adult. *D. insulare* avoided superparasitism and multiple parasitism of larvae already parasitized by *M. plutellae*. *M. plutellae* generally avoided superparasitism but could not detect eggs of *D. insulare* for at least 12 h after they were oviposited in the host. The first-instar larva of *M. plutellae* was intrinsically superior to the first instar of *D. insulare* and survived when eggs of both species of parasites were oviposited simultaneously in the same host. However, first-instar larvae of *M. plutellae* were intrinsically inferior to second or later instars of *D. insulare*. Thus, it is important for *M. plutellae* to detect larvae parasitized by *D. insulare* more than 12 h previously.

Introduction

The diamondback moth, *Plutella xylostella* (L.), is an important pest of cole crops in many regions of the world. Comprehensive reviews on biology, life history and economic importance can be found in Harcourt (1954), Peng (1975), Butts (1979), and Smith (1982). *P. xylostella* is a pest on cabbage, cauliflower, broccoli, turnip, rape, canola and mustard in Canada (Harcourt 1960; Putnam 1973; Anon. 1978; Turnock 1982), and is responsible for most of the insect damage on Brussels sprouts in Ontario (Butts 1979; Smith 1982).

Although many species of predators have been observed feeding on the larvae of *P. xylostella* (Hardy 1938; Harcourt 1960; Pimentel 1961; Burgess 1980), predators and pathogens are not as important as parasites in reducing populations of *P. xylostella* in Ontario (Harcourt 1960). According to Goodwin (1979) over 90 species of parasites attack the larvae and pupae of *P. xylostella*. Comprehensive reviews of the parasites, most of which are Hymenoptera attacking first- to third-instar larvae, can be found in Hardy (1938), Herting (1975), Peng (1975), Butts (1979), and Goodwin (1979).

The most numerous parasites reared from *P. xylostella* collected at Cambridge, Ontario in 1980 and 1981 were *Diadegma insulare* (Cress.), *Diadromus subtilicornis* (Grav.) and *Microplitis plutellae* Mues. *D. subtilicornis* is an ichneumonid that attacks prepupae and pupae whereas *D. insulare*, also an ichneumonid, and *M. plutellae*, a braconid, attack larval hosts.

In Ontario and New York, the parasite complex of *P. xylostella* does not provide adequate control of *P. xylostella* when conditions favour increased numbers of moths (Harcourt

1960; Pimentel 1961; Putnam 1973). However, eliminating this pest on cabbage is unnecessary because low levels can be tolerated by growers. Consequently, there is a potential for developing effective biological control for *P. xylostella* on this crop. Biological control is a particularly important consideration because the diamondback moth is becoming resistant to several insecticides (Lee and Lee 1979; Ooi 1979; Smith 1982). Before the release of any introduced species of parasite to control the moth in Ontario, observations on the life histories, population dynamics and competitive abilities of the endemic parasites are needed. This paper presents observations of the competitive abilities of the larval parasites *D. insulare* and *M. plutellae*.

Materials and Methods

A laboratory culture of *P. xylostella* was established from larvae and pupae collected at Cambridge, Ontario during the summers of 1980 and 1981. They were reared on cabbage leaves. Parasites were reared from larvae and pupae of *P. xylostella* collected in the field and the cultures maintained using laboratory-reared host larvae. Adults of both *P. xylostella* and its parasites were fed a 20% honey solution and misted daily with water.

Second-instar host larvae, parasitized by either *D. insulare* or *M. plutellae*, were held at seven constant ($\pm 1^\circ\text{C}$) temperatures: 13, 15, 17, 19, 21, 23 and 25°C , all at 60% RH (Winston and Bates 1960) to determine the threshold for development, t , and the thermal constant, K , for both parasites. The stages of development of both species of parasites at 25°C was studied by periodic dissection of parasitized host larvae in Pringle's solution under a dissecting microscope and measuring the width of the head capsule of the parasites.

The fecundity of both species was determined at 17, 19, 21, 23 and 25°C . A small cabbage leaf (ca. 50 cm^2) was placed in a 500-ml cardboard cup, and raised from the bottom by a double layer of wire screen. The lid consisted of a 250-ml plastic cup with a 2.2-cm hole cut in the side. This was inverted over the cardboard cup and a No. 3 rubber stopper used to plug the hole in the side (Parker and Pinnell 1973). Previous observations showed that *D. insulare* was capable of parasitizing up to 80 larvae per day at 25°C , thus 100 larvae were presented daily to each of five female *D. insulare* at 23 and 25°C until death. Eighty larvae were offered daily at 21°C , and 60 at each of 17 and 19°C to ensure that non-parasitized larvae were available to each female at all times during a 24-h period. On the basis of results obtained by Putnam (1968) each of five female *M. plutellae* was provided daily with 30 host larvae at each temperature. Larvae were placed on the cabbage leaf in a container and the parasite introduced immediately before the container was placed in a constant-environment chamber maintained at the desired temperature and 16hL: 8hD. Relative humidity was maintained at ca. 50% by placing a tray of water at the bottom of the chamber. Host larvae were dissected 12–24 h after the removal of the adult parasite from the cup and the number of eggs laid per female was recorded.

Development of the ovaries was studied by dissecting three or four virgin female parasites, held at 17°C , every five days after eclosion. The ovaries were removed and placed directly in a drop of Pringle's solution on a microscope slide. The ovaries were separated, dissected and the eggs were stained using a drop of Belling's iron acetocarmine. The number of eggs per ovary was recorded.

The host-searching behaviour of females of both species was studied by placing five second-instar larvae on a fresh cabbage leaf in a container into which a mated, female parasite was introduced. The time taken for the parasite to attack the first host was recorded. In a second experiment the larvae were allowed to feed on the leaf for several hours before the female parasite was introduced. Five females of each species of parasite were observed for each experiment.

The distribution of eggs among hosts by the parasites was determined by introducing individual mated females into containers with host larvae on a cabbage leaf. One hundred second-instar larvae were presented to each of five *D. insulare* and 30 larvae to each of six *M. plutellae*. The parasites were left with their hosts for 24 h then the latter were dissected in Pringle's solution and the number of eggs per larva recorded. The experiment was repeated with only 40 larvae provided to each female *D. insulare*. The average observed distribution of eggs produced by the females of each species was compared to that predicted by the random distribution using the Chi-square goodness-of-fit test.

The ability of female parasites to avoid superparasitism and multiparasitism by discriminating between previously parasitized and non-parasitized host larvae, was tested. Five non-parasitized and five parasitized larvae were placed on a cabbage leaf in a petri dish. The leaf was supported by a wire screen. Dayglo® dye was used to mark the parasitized larvae for easy identification. A preliminary experiment, using marked and unmarked non-parasitized larvae, had ensured that the use of the dye did not introduce a bias (Bolter 1982). Five, two- to three-day-old, mated, female parasites were used in each replication of the experiment. A female was introduced into the petri dish and its choice of parasitized and non-parasitized larvae was recorded. In an effort to minimize the effect of the changing ratio of parasitized to non-parasitized hosts, a parasite was removed from the dish as soon as it had stung half the available hosts. Each female of *D. insulare* was given four lots of 10 larvae: each female of *M. plutellae* was given two lots. Previous observations had shown that *M. plutellae* was capable of parasitizing only half as many hosts in a given period as *D. insulare*.

To establish whether the ability to discriminate between parasitized and non-parasitized hosts changes with the age of the immature parasite, an experiment was performed three times using hosts parasitized 0, 12 or 24 h previously. For easy recognition of the immature parasites the larvae were reared at 25°C for approximately 36 h before dissection.

Results and Discussion

Head capsule widths, which conformed to Dyar's law, indicated that both parasite species had four larval instars. The eggs and larvae of each species were easily distinguishable. The symmetrical, hydropic egg of *D. insulare* measured on average 0.28×0.06 mm ($n = 30$) when it was oviposited and expanded to 0.60×0.13 mm ($n = 30$) just before hatching. The first-instar larva was typically ichneumonoid with small falcate mandibles and a long tapering caudal appendage which decreased in size with successive instars. Development of *D. insulare* was continuous and the developmental time from egg to adult decreased at higher temperatures, ranging from an average of 15.6 ± 1.5 days at 25°C to 42.3 ± 1.7 days at 13°C (Table I).

The eggs of *M. plutellae* differed from those of *D. insulare* in having one end wider than the other. They were also hydropic and measured on average 0.34×0.07 mm ($n = 30$) at oviposition and 0.70×0.22 mm ($n = 30$) just before hatching. The first-instar larva was mandibulate with a caudal vesicle which increased in size with successive instars. The second instar, which also was mandibulate, remained in this stage for an extended period and did not develop further until the host moulted into the fourth instar. Development from egg to adult for *M. plutellae* was also faster at higher temperatures and varied from an average of 15.1 ± 1.2 days at 25°C to 48.1 ± 3.2 days at 13°C (Table I). The thermal requirements for *D. insulare* (282°D_{66}) and *M. plutellae* ($218^\circ\text{D}_{9.2}$) showed that these parasites were synchronized with their hosts which, according to Harcourt (1954), have a thermal requirement of $283^\circ\text{D}_{7.3}$. The thermal requirements also indicated that the parasites would have four to six generations per year in Ontario, as does *P. xylostella*.

Table I. Days for development from egg to adult of *D. insulare* and *M. plutellae* at seven constant temperatures

Temp. (°C)	<i>D. insulare</i>			<i>M. plutellae</i>		
	No. observed	Development (days)		No. observed	Development (days)	
		Mean	S.E.		Mean	S.E.
13	74	42.3	1.7	80	48.1	3.2
15	94	36.0	1.7	90	42.1	2.8
17	92	27.2	2.4	94	29.8	2.4
19	84	22.1	2.1	86	22.2	1.5
21	87	19.4	1.6	88	18.2	1.3
23	84	17.4	1.4	88	16.3	1.2
25	94	15.6	1.5	84	15.1	1.2

High temperatures reduced longevity of mated females of both species of parasite. Mean longevity ranged from 21.2 days at 25°C to 43.6 days at 17°C for *D. insulare* and from 21.6 days at 25°C to 37.8 days at 17°C for *M. plutellae* (Table II). Mated females lived for approximately the same length of time whether or not they were provided with hosts. The mean fecundity of *D. insulare* ranged from an average of 595.4 eggs at 17°C to 813.8 eggs at 23°C. Fecundity decreased slightly from 23 to 25°C (Table III). Fecundity of *M. plutellae* remained near an average of 309 eggs throughout the temperature range from 17 to 25°C (Table III). Thus, at temperatures from 17 to 25°C, *D. insulare* would have an advantage over *M. plutellae* provided both species could find all of the necessary hosts in which to oviposit.

Table II. Longevity of mated female *D. insulare* and *M. plutellae*, provided with honey and water and given hosts continuously throughout life at various constant temperatures

Temp. (°C)	No. of parasites	Longevity (days) ¹	
		<i>D. insulare</i>	<i>M. plutellae</i>
17	5	43.6a	37.8a
19	5	40.0ab	33.4a
21	5	30.6b	23.0b
23	5	25.7bc	20.0b
25	5	21.2c	21.6b

¹Means in the same column followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).

Table III. Fecundity of mated female *D. insulare* and *M. plutellae* at constant temperatures

Temp. (°C)	No. of parasites	No. larvae per day	Number of eggs/female ¹	
			<i>D. insulare</i>	<i>M. plutellae</i>
17	5	60	594.4a	291.6a
19	5	60	730.6b	289.4a
21	5	80	763.0bc	320.6ab
23	5	100	813.8d	315.8ab
25	5	100	786.2cd	324.4b

¹Means in the same column followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).

Both species of parasites have long lateral oviducts modified for storage of eggs. *D. insulare* have the *Ophion*-type of oviduct with the oviducts longer than the ovaries. Each oviduct contained as many as 50 eggs. The oviducts of *M. plutellae* are of the *Apanteles*-type in which the oviducts are shorter than the ovaries, and up to 40 eggs were stored in each. *M. plutellae* laid only about one-half of its available eggs in a 24-h period, whereas *D. insulare* laid all its eggs in this time when provided with enough hosts. Both *D. insulare* and *M. plutellae* have synovigenic ovarioles, and were able to produce eggs throughout their adult lives. Female *D. insulare* did not oviposit for 24 h after eclosion while oviposition by *M. plutellae* occurred within 2–3 h. The ovarioles of both species were polytrophic. Egg production in *D. insulare* was monootene while in *M. plutellae* it was polyootene. Host larvae were not required to stimulate ovigenesis which occurred continuously throughout the life of the parasites. Both species had the ability to absorb oocytes. The number of eggs per ovary decreased as the females aged when no hosts were present (Table IV). The processes of ovigenesis and ovisorption resulted in the capability for deposition of fresh eggs even after long periods without exposure to hosts.

Table IV. Number of eggs per ovary in *D. insulare* and *M. plutellae* at 5-day intervals after eclosion (no hosts present)

Days after eclosion	<i>D. insulare</i>		<i>M. plutellae</i>	
	Number dissected	No. per ovary ¹	Number dissected	No. per ovary ¹
1	—	—	4	27.8a
5	4	39.0a	4	35.0a
10	4	39.4a	4	33.1a
15	—	—	4	22.5ab
20	4	37.4a	3	17.3b
25	3	17.7b	3	14.9b
30	3	16.9b	4	15.5b
35	3	15.3b	4	16.1b
40	3	15.8b	—	—

¹Means in the same column followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).

Females of *D. insulare* took significantly longer to parasitize the first of five hosts if there was no damage to leaves by host larvae (Table V). Feeding damage stimulated exaggerated searching behaviour; females explored holes in the leaf thoroughly with antennae, tarsi and ovipositors. However, searching for hosts appeared random in *D. insulare* even when the larval hosts had damaged the leaves.

Table V. Time required for *D. insulare* and *M. plutellae* to parasitize the first of five *P. xylostella* provided to each parasite

Parasite	No Larval Feeding			Larval Feeding		
	Number observed	Time ¹ (secs)		Number observed	Time ¹ (secs)	
		Mean ²	S.E.		Mean ²	S.E.
<i>D. insulare</i>	5	48.0a	16.7	5	24.0b	8.9
<i>M. plutellae</i>	5	37.5ab	19.4	5	9.3c	4.0

¹Time to parasitize measured as soon as parasite began searching.

²Means in columns and rows followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).

When hosts were added to the leaf immediately prior to the introduction of a female of *M. plutellae*, the parasite walked randomly over the leaf moving its antennae from side to side until it found a larva. Under these conditions, location of the first host larva took about the same time for *M. plutellae* as for *D. insulare* (Table V). However, unlike *D. insulare*, females of *M. plutellae* were attracted to the frass produced by feeding larvae. When a female was introduced into a container of larvae that had been allowed to feed before the experiment, it flew directly onto the frass on the leaves and began to search in the immediate area. This behaviour has been observed in many parasites and it has been proposed that they are attracted to kairomones in fresh frass of the host (Vinson 1976) although they also may be attracted to plant exudates resulting from larval feeding. The time taken by *M. plutellae* to find a larva under these conditions was significantly less than with either non-feeding hosts or by *D. insulare* (Table V). These results suggest that *M. plutellae* is extrinsically superior. However, observations on host-searching behaviour indicate that both males and females of *D. insulare* are attracted to the cabbage plant, and would seek out a plant in the laboratory even when host larvae have not been feeding.

Females of *D. insulare* oviposited an average of 0.71 eggs per host larva when presented with 100 hosts for a 24-h period (Table VI). The distribution of eggs among host larvae was non-random (Table VI), indicating that the parasite could distinguish between previously parasitized and non-parasitized larvae. When the number of hosts available to a female was reduced to 40, which is fewer than the parasite is capable of parasitizing in a 24-h period, the distribution of eggs was still non-random (Table VI).

Table VI. Frequency distribution of eggs deposited by *D. insulare* and *M. plutellae* per larva of *P. xylostella* after 24-h exposure to the parasite

Experiment (Parasite + hosts)	Number observed	Frequency of Oviposition by Parasite				Total mean no./larva	X ² ¹
		Larvae with 0 eggs	Larvae with 1 egg	Larvae with 2 eggs	Larvae with 3 eggs		
<i>D. insulare</i> + 100 2nd- instar larvae	5	29.2 (49.2)	67.8 (34.9)	1.8 (12.4)	0.2 (2.9)	0.71	50.7 ²
<i>D. insulare</i> + 40 2nd- instar larvae	5	6.6 (15.6)	27.4 (14.7)	3.6 (7.0)	0.8 (2.6)	0.95	18.9 ²
<i>M. plutellae</i> + 30 2nd- instar larvae	6	11.3 (14.2)	16.3 (10.6)	1.7 (4.0)	0.6 (1.0)	0.75	5.1 ³

¹X²-value calculated from expected values for random distribution (shown in parenthesis) and observed values.

²Significantly different from expected at $P \leq 0.05$ (Tabular $X^2 = 9.49$, d.f. = 4).

³Not significantly different from expected at $P \leq 0.05$ (Tabular $X^2 = 11.1$, d.f. = 5).

Females of *M. plutellae* oviposited an average of 0.95 eggs per host when presented with 30 hosts for a 24-h period and distributed their eggs randomly ($P \leq 0.05$, Table VI). This suggested that *M. plutellae* was unable to distinguish between parasitized and non-parasitized larvae. However, superparasitism may not occur readily in the field because the parasite would not be confined for 24 h with a limited number of hosts.

The number of non-parasitized larvae 'probed' by *D. insulare* and *M. plutellae* was not significantly different from the number of parasitized larvae 'probed' (Table VII). Females of both species were unable to distinguish between parasitized and non-parasitized hosts from external cues, and apparently relied on sensory stimulation of the ovipositor once it had been inserted into the host.

Table VII. Average number of *P. xylostella* "probed" by five female *D. insulare* or *M. plutellae* when 50% of hosts were previously parasitized, and the number of hosts containing two parasite eggs

Experimental parasite	State of hosts	Hours After First Parasitization					
		0		12		24	
		Number larvae probed	Hosts with 2 eggs	Number larvae probed	Hosts with 2 eggs	Number larvae probed	Hosts with 2 eggs
<i>D. insulare</i> ²	Parasitized by <i>D. insulare</i>	9.0a	0.4c	10.2a	0.2c	10.6a	0.0c
	Non-parasitized	11.0a	0.2c	9.8a	0.0c	9.4a	0.2c
<i>D. insulare</i>	Parasitized by <i>M. plutellae</i>	8.4a	0.2c	10.0a	0.2c	9.6a	0.0c
	Non-parasitized	11.6a	0.0c	10.0a	0.2c	10.4a	0.2c
<i>M. plutellae</i> ³	Parasitized by <i>M. plutellae</i>	5.4b	0.4c	5.6c	0.2c	4.8b	0.2c
	Non-parasitized	4.6b	0.2c	4.4b	0.2c	5.2b	0.0c
<i>M. plutellae</i>	Parasitized by <i>D. insulare</i>	5.2b	5.2b	4.2b	2.4d	6.0b	0.2c
	Non-parasitized	4.8b	0.4c	5.8b	0.2c	4.0b	0.0c

¹Means in columns and rows followed by the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).

²Females of *D. insulare* were allowed to parasitize 20 larvae.

³Females of *M. plutellae* were allowed to parasitize 10 larvae.

Superparasitism

Neither *D. insulare* nor *M. plutellae* avoided superparasitism completely, however superparasitism by either species occurred infrequently (Table VII). An average of less than 5% of the host larvae were found to contain two parasite eggs in each experiment using five females. When two eggs of either parasite were deposited in the same host, one was usually smaller, suggesting that the eggs were not laid at the same time. This "breakdown in restraint" has been observed in several species of parasites (Salt 1933; Douth 1959; Bakker *et al.* 1967; Greany and Oatman 1972) and it is usually associated with a lack of healthy hosts or a high parasite to host ratio (Van Lenteren *et al.* 1978; Lawrence 1981) or inexperienced female parasites (Van Lenteren *et al.* 1978). Thus, both species of parasite were able to distinguish the presence of an egg of its own species after 0, 12 and 24 h and thus avoid superparasitism.

Multiple Parasitism

Female *D. insulare* avoided multiparasitism of hosts containing eggs or larvae of *M. plutellae* after 0, 12 and 24 h (Table VII). Female *M. plutellae*, however, were unable to detect the presence of a recently deposited egg of *D. insulare* within a host. All of the hosts parasitized by *D. insulare* within the previous 12 h that were probed by *M. plutellae* contained two eggs,

one of each species. When the egg of *D. insulare* was 12 h old, females of *M. plutellae* were able to discriminate to some extent and parasitized only 60% of the previously parasitized larvae that they probed. When the eggs of *D. insulare* were 24 h old, females of *M. plutellae* were able to discriminate and avoided multiparasitism (Table VII). In order to understand the significance of these results it was necessary to observe the outcome of the intrinsic competition which occurred as a result of superparasitism and multiparasitism.

Intrinsic Competition

Competition occurs between supernumary parasites if a host can support the development of only a single parasite. In the field it would be advantageous for a female to avoid superparasitism or multiple parasitism of a host which could lead to the waste of an egg.

In the 30 hosts where eggs of *D. insulare* and *M. plutellae* were deposited simultaneously, the 1st-instar larva of *M. plutellae* always survived by physically attacking the larva of *D. insulare*. *M. plutellae* remained in the aggressive second-instar stage for an extended period (up to 8 days at 25°C) and killed both first- and second-instar larvae of *D. insulare*. However, if the egg of *M. plutellae* hatched when the larva of *D. insulare* was in the early second-instar stage (i.e., more than 24 h old), the first-instar larva of *M. plutellae* was attacked and killed. When the egg of *M. plutellae* was deposited into a host containing third- and fourth-instar *D. insulare* the egg either failed to hatch or the newly emerged larva failed to develop and was encapsulated by host cells. This could be a result of physiological suppression caused by the presence of the larger parasites as has been previously reported by Fisher (1961).

M. plutellae was intrinsically superior to *D. insulare* unless it was in the first instar when *D. insulare* was in the second, third or fourth instar. This explains why it was advantageous for the adult female of *M. plutellae* to detect the presence of eggs of *D. insulare* that had been in the host for more than 12 h. When an egg of *M. plutellae* was oviposited in a host that had contained *D. insulare* for at least 12 h, the larva of *D. insulare* would be in the late-first or early-second instar when the larva of *M. plutellae* emerged (at 25°C, the duration of the egg stage for *M. plutellae* was ca. 2 days while *D. insulare* remained as an egg for ca. 1.5 days). In this situation the outcome of physical competition would not be predictable. If *D. insulare* had oviposited in the host 24 h before *M. plutellae* oviposited, the larvae of *D. insulare* would have moulted into its second instar before the egg of *M. plutellae* hatched, and *D. insulare* would survive. *D. insulare* avoided all hosts that had been parasitized by *M. plutellae* and did not initiate multiple parasitism which would have suppressed or killed its larvae.

Summary

M. plutellae develops faster at temperatures of 13 to 17°C than *D. insulare* but the rates are reversed at temperatures of 21 to 25°C, yet *M. plutellae* lives for a shorter period of time than *D. insulare* at most temperatures. The number of eggs produced per day is similar for both species which results in a much larger fecundity for *D. insulare*. *M. plutellae* begins to oviposit sooner after emergence than *D. insulare*, however both species begin to oviposit within 24 h and both species avoid superparasitism and thus do not waste eggs. *M. plutellae* is intrinsically superior to *D. insulare* unless it is in the first instar when *D. insulare* is in its second to fourth instar. However, *D. insulare* avoids multiple parasitism with *M. plutellae*.

These attributes permit coexistence of *D. insulare* and *M. plutellae* in the field and allow them to contribute to the natural control of *P. xylostella* in ephemeral ecosystems such as annual field crops.

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THE POTENTIAL OF CARBON DIOXIDE AND LOW-OXYGEN ATMOSPHERES FOR CONTROL OF WINTER EGGS OF THE EUROPEAN RED MITE, *PANONYCHUS ULMI* (ACARI: TETRANYCHIDAE), ON HARVESTED APPLES

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Abstract

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The effect of carbon dioxide combined with low levels of oxygen on winter eggs of the European red mite, *Panonychus ulmi* (Koch), on harvested apples was investigated under two temperature regimes (0.5 to 3.3 and 12°C) with exposure periods from 2 to 191 days. The eggs were killed in atmospheres of 75% carbon dioxide and 1% oxygen or 9% carbon dioxide and 0.5% oxygen at 12°C with a 4-day exposure period. Similar results were also obtained in an atmosphere containing 65% carbon dioxide and 2.5% oxygen in a 14-day exposure period. The combined effects of low oxygen and a high concentration of carbon dioxide appear to be necessary for complete control, particularly at temperatures around 1°C.

Introduction

Controlled atmospheres are widely used in the storage of such perishable commodities as fruit, vegetables and cut flowers to retard ripening and reduce spoilage. Also, they can be used to control insects in stored commodities (Morgan and Gaunce 1975; Aharoni *et al.* 1981; Lidster *et al.* 1981). Insects and other arthropods can be killed by exposure to atmospheres containing high concentrations of carbon dioxide or low levels of oxygen at room temperature. Herne and Bond (1981) have shown that high concentrations of carbon dioxide were effective against winter eggs of the European red mite on harvested apples treated at 12 to 25°C. High mortality was obtained with atmospheres containing 75% carbon dioxide and complete mortality was achieved with 90% carbon dioxide. Morgan and Gaunce (1975) also found that concentrations higher than 90% carbon dioxide at temperatures of 12°C or greater would kill San José scale on harvested apples.

Presented here are results of further experiments on the control of winter eggs of the European red mite on harvested apples using atmospheres containing low levels of oxygen and high and low concentrations of carbon dioxide.

Materials and Methods

The tests were carried out in two successive years; in the first year (1981-82) 'McIntosh' and 'Red Delicious' apples were used whereas in the second year (1982-83) only the 'Red Delicious' cultivar was tested. The apples were picked at the normal harvest time (21 September to 5 October) from mite-infested trees in experimental orchards of the Ontario Ministry of Agriculture and Food, Norfolk county and of Agriculture Canada, Research Station, Vineland Station, Ontario.

In 1981-82 the 'Red Delicious' apples were taken to the Research Centre, Agriculture Canada, London, Ontario and treated at 1-2°C and 80-95% RH with $3 \pm 1\%$ oxygen and $5 \pm 1\%$ carbon dioxide for periods of 7 to 42 days. After treatment the apples were returned to cold storage (1°C) at the Vineland Growers Cooperative, Jordan Station, Ontario until 30 April 1982. Other lots of 'Red Delicious' and 'McIntosh' apples were stored under commercial conditions with low oxygen at the Norfolk Fruit Growers Association's low-oxygen storage facility at Simcoe, Ontario for periods up to 191 days to determine the effect of these conditions on the mite eggs. The temperature for the treatment at Simcoe was 2.2 - 3.3°C, the oxygen concentration was 0.7 - 1.5% and carbon dioxide 0.7 - 1.0%.

In 1982-83 the 'Red Delicious' apples were treated at London with 5 and 75% concentrations of carbon dioxide and 0.5 - 2.5% concentration of oxygen at 1 and 12°C for periods of 2-21 days. The treatments were carried out in 525-l fumigation chambers described by Monro and Buckland (1955). After the apples had been placed in the chambers, the atmospheres were evacuated twice to a pressure of 190 mm Hg and each time restored to normal pressure with nitrogen. After one additional evacuation to 190 mm, carbon dioxide was added to the desired concentration and the pressure restored to atmospheric with an appropriate amount of nitrogen. In this way the oxygen levels in the chambers were brought to ca 0.5-2.5% and carbon dioxide to ca 5 or 75%. Apples in the control group were subjected to the same pressure changes except that air was used to restore atmospheric pressure instead of nitrogen. A container of water was placed in each chamber to maintain humidity at 80-100% RH. The concentrations of carbon dioxide and oxygen in the chambers were determined by gas chromatography using PORAPAK N and molecular sieve 13X, respectively, in 2 m $\times$ 3 mm ID stainless steel columns at 50°C with helium flowing at 15 ml per min as the carrier and using a thermal conductivity detector. Under these conditions the retention time for carbon dioxide was 1.4 min and for oxygen 1.7 min.

To break egg diapause after treatment, the test apples were returned to cold storage at 1°C for over 160 days at the Vineland Growers Cooperative, Vineland Station, Ontario. The effects of the treatments were assessed by removing the apples from cold storage to a room at 20°C and 65% RH, counting the total number of eggs at the calyx end of the apples, ringing them with Stickem¹ to capture emerging mites and incubating until hatching was complete. Larvae were counted and removed from the Stickem each day so that the total emergence would be determined. The effectiveness of the treatments was thus established in terms of egg mortality. Each treatment was repeated 4 times using one apple per replicate.

Results and Discussion

Mite eggs on harvested apples were controlled at 12°C with both high and low concentrations of carbon dioxide plus low levels of oxygen (Table I). One hundred per cent mortality was attained after 4 days exposure to atmospheres with 75% carbon dioxide + 1% oxygen and with 9% carbon dioxide + 0.5% oxygen. Some eggs survived in both treatments for 2 or 3 days, but even so, >96% mortality was achieved when the high concentration of carbon dioxide was used. When low levels of carbon dioxide were used in conjunction with low oxygen levels, more eggs survived when the exposure was reduced to less than 4 days.

At 1°C, complete mortality was achieved by treatment with an atmosphere containing 65% carbon dioxide + 2.5% oxygen in a 14-day exposure period (Table II). In this case 100% mortality was obtained only when the atmosphere consisted of a high concentration of carbon dioxide with a low level of oxygen. Without a high concentration of carbon dioxide, some eggs survived even after prolonged exposure periods. Under laboratory conditions (Table III) and under commercial conditions at Simcoe in the 1981-82 season (Table IV) at 1-3°C

¹Stickem Special, Michel and Pelton Co.
Emeryville, Calif., U.S.A.

using low levels of oxygen and carbon dioxide, complete mortality could not be assured even by treatments up to 191 days. In all tests the apples were not adversely effected by the treatments.

Table I. Mortality of European red mite eggs on 'Delicious' apples exposed to low levels of oxygen and high and low concentrations of carbon dioxide at 12°C for periods up to 4 days. (1982-83 tests)

Treatment Conditions			Mortality (%)
CO ₂ (%)	O ₂ (%)	Exposure Time (Days)	
75	0.5	2	96.3
72	1.0	3	99.8
75	1.0	4	100.0
7	0.5	2	51.8
4	1.0	3	94.6
9	0.5	4	100.0
control			0.0

Table II. Mortality of European red mite eggs on 'Delicious' apples exposed to low levels of oxygen and high and low concentrations of carbon dioxide at 1°C for periods up to 21 days. (1982-83 tests)

Treatment Conditions			Mortality (%)
CO ₂ (%)	O ₂ (%)	Exposure Time (Days)	
74	1.0	2	22.5
72	0.5	3	61.9
75	1.0	4	75.9
68	1.5	7	86.4
65	2.5	14	100.0
75	1.5	21	100.0
8	1.5	2	32.1
4	1.5	3	11.1
6	1.0	4	9.1
4	0.5	7	32.7
4	2.5	14	95.3
4.5	2.5	21	97.5
control		4	4.6
control		21	39.1

Table III. Mortality of European red mite eggs on 'Delicious' apples exposed to 3% oxygen and 5% carbon dioxide at 1-2°C and 80-95% RH for periods of 7-42 days. (1981-82 tests)

Exposure (days)	No. of eggs	Mortality (%) ¹
7	5122	23.3
14	5870	73.2
21	3839	81.6
28	5257	88.6
35	4218	83.0
42	3459	93.2
control	3031	19.4

¹Average of 4 replicates

Table IV. Mortality of European red mite eggs on 'Delicious' and 'McIntosh' apples stored in controlled atmosphere storage (0.7-1.5% O₂ and 0.7-1.0% CO₂) at 2.2-3.3°C for periods up to 191 days. (1981-82 tests)

Storage period (days)	Apple cv ¹	No. of eggs	Mortality (%) ²
52	D	1243	99.9
69	M	1735	99.8
117	D	1499	99.9
134	M	899	99.9
145	D	1736	100.0
162	M	1533	99.9
174	D	1205	99.9
191	M	1037	99.9
control	D	2877	26.8
control	M	1775	11.9

¹D = Delicious CV, M = McIntosh CV

²Average of 4 replicates

These experiments indicate that living eggs of the European red mite can be eradicated from harvested apples in a practical length of time and at temperatures compatible with quality preservation procedures, by appropriate manipulation of the atmosphere. The combined effects of low oxygen and high concentrations of carbon dioxide appear to be essential to give complete mortality, particularly at temperatures of ca 1°C; low levels of oxygen alone seem insufficient to kill all eggs. Further tests should be made to define precise conditions for control that would be adaptable to modern storage regimes.

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IDENTIFICATION OF A BLEND OF SEX PHEROMONE COMPONENTS OF THE POTATO STEM BORER (LEPIDOPTERA: NOCTUIDAE) FOR MONITORING ADULTS

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Abstract

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Analysis of sex pheromone gland dips obtained from calling *Hydraecia micacea* (Esper) females indicated the presence of four 14 carbon acetates. These compounds were identified by high resolution gas chromatography and mass spectroscopy as tetradecan-1-ol acetate (68.9%), (Z)-9-tetradecen-1-ol acetate (3.4%), (E)-11-tetradecen-1-ol acetate (14.6%), (Z)-11-tetradecen-1-ol acetate (13.1%). Field traps baited with 500 µg of the four-component blend were significantly more attractive than were those baited with three virgin females. Deletion of (Z)-9-tetradecen-1-ol acetate from the four-component blend reduced trap captures to a level not significantly different from blank traps.

Introduction

The potato stem borer, *Hydraecia micacea* (Esper), is a pest of both corn and potatoes in eastern Canada (Deedat and Ellis 1983). Although damage is often sporadic, as many as 80% of the corn plants in some fields have been killed (Tetor 1980). The distribution of *H. micacea* is patchy within fields and variable between fields (Deedat and Ellis 1983) which makes it difficult to accurately monitor adult populations by using light traps. Further, the larval habit of feeding within the host plant and migrating into fields from numerous non-agricultural hosts surrounding fields make it difficult to control with insecticide sprays (Deedat *et al.* 1983). The potato stem borer is an imported pest (Gibson 1908) with few natural enemies. Although imported parasites have been released, it will be several years before any control by these insects will become obvious. Sex pheromones have been effectively used for population monitoring and control of many pest insects (Mitchell 1981), and may provide economically sound and effective control for the potato stem borer. The following reports the identification of a highly effective blend of pheromone components for the potato stem borer and the results of field tests using this blend.

Materials and Methods

General. Potato stem borers used in this study were from second- and third-generation laboratory colonies reared on an artificial diet (West 1984). Female pupae were maintained as described by West *et al.* (in press). Newly emerged adult females were transferred daily to plexiglass cages and were maintained under conditions described by West *et al.* (in press) for 48 h prior to use. Only actively calling females were used for collection of the pheromone. Pheromone was collected by removing the extended terminal abdominal segments and dipping them in a conical microvial containing iso-octane (Fisher 99 mole %). The pheromone from 5-10 females was collected in 10-20 µl of solvent in each microvial and the samples were analyzed by gas-liquid chromatography without solvent evaporation.

Chemical Analysis. Samples were analyzed by high resolution capillary gas-liquid chromatography (GC) using a Hewlett-Packard 5792[®] GC interfaced to a Hewlett-Packard 3390[®] reporting integrator. The gas chromatograph was equipped with a split/splitless injector and a flame ionization detector. Helium was used as the carrier gas at a linear flow

velocity of 18 cm/sec. The fused silica columns used for chromatographic analyses included a 15 m $\times$ 0.15 mm (ID) column coated with cross-linked methyl silicone (Hewlett-Packard) and a 25 m $\times$ 0.22 mm (ID) BP 20[®] (Carbowax 20 M) column (SGE). Conditions of chromatography were as follows: initial temperature = 80°C for 1 min, splitless purge at 30 sec, temperature program = 30°C/min, final temperatures of 150°C (methyl silicone) and 180°C (BP 20). Internal standards used for all GC analyses included the saturated acetates of dodecanol and hexadecanol. Equivalent chainlength values of components eluting during the analyses of the natural product samples were calculated and compared with those of candidate synthetic compounds (Teal *et al.* 1981). Tentative chemical assignments were made. Further support for these assignments came from co-chromatography of the natural product with 5 ng of each of the synthetic components.

GC-mass spectral analyses were performed using a VG 1212 F mass spectrometer interfaced to a Hewlett-Packard 5792 GC equipped with a cool-on column injector. Both electron impact and chemical ionization (CH₄) spectra were obtained. The columns used for these analyses were 50 m $\times$ 0.24 mm (ID) DB 5[®] (J and W) and 30 m $\times$ 0.25 mm (ID) SBP1[®] (Supelco) fused silica columns. Helium was used as the carrier gas at a linear flow velocity of 18 cm/sec. Samples were injected at 80°C and after the solvent front had eluted the temperature was programmed at 10°C/min to a final temperature of 250°C. Spectra of compounds eluting from samples were compared with those of synthetic components.

Field Studies. Synthetic chemicals used in the formulation of lures were obtained from Albany International Co. and Sigma Chemical Co. All compounds were analyzed by capillary GC and, if less than 98% pure, were purified by high performance liquid chromatography on a 25 cm $\times$ 2.5 cm (OD) AgNO₃-silica column eluted with toluene (Heath and Sonnet 1980). Rubber septa dispensers, Soxhlet extracted for 12 h each in acetone and hexane, were air dried and then impregnated with 500 μ g of the test blends. Blends were formulated using the vapor pressure release model described by Heath *et al.* (1984). Volatile collections from these septa using the technique of Tumlinson *et al.* (1982) indicated that the percentage release of all compounds was within 5% of that calculated for each compound using the formula of Heath *et al.* (1984).

Field tests were conducted during August 1983 in a cornfield at the University of Guelph, Arkell Research Station, and on a private farm near Guelph, Ontario in a field planted for the first time in white beans after several years of planting in corn. Albany International *Heliothis* Traps[®] were spaced 20 m apart at about 1 m from the ground and were baited with a lure, 3 caged virgin females or a blank septum. The positions of the septa and females in each of the 3 replicates per experiment were randomized daily and the number of males captured was recorded. Females were replaced at 3-day intervals and lures were replaced every 2 weeks. Data were transformed by $\sqrt{x} + 0.5$ prior to analysis of variance and a Duncan's multiple range test. The number of males captured in pheromone-baited traps on the farm near Guelph was also compared with the number of potato stem borers captured in a light trap positioned near the pheromone traps.

Results and Discussion

Injection of the natural product samples onto the methyl silicone column produced 4 distinct peaks in the C₁₄ acetate region with incomplete separation of the 3 major components (Fig. 1A). Analysis using the BP 20 column resolved the 4 peaks, again in the C₁₄ acetate region (Fig. 1B). ECL values of the 4 natural product peaks on both columns were identical (within 0.5 ECL units) to tetradecan-1-ol acetate (14:Ac), (Z)-9-tetradecen-1-ol acetate (Z9-14:Ac) (E)-11-tetradecen-1-ol acetate (E11-11:Ac) and (Z)-11-tetradecen-1-ol acetate (Z11-14:Ac). Several other peaks were variably present but were also present in solvent blank analyses. Mean percentages of the components were 68.9% 14:AC, 3.4% Z9-14:AC, 14.6%

E11-14:AC and 13.1% Z11-14:AC. The mean amount of the total blend per female was 3.6 ng. Co-chromatography of the individual synthetic compounds, tentatively identified above, with the samples on both GC columns added further support to the chemical assignments.

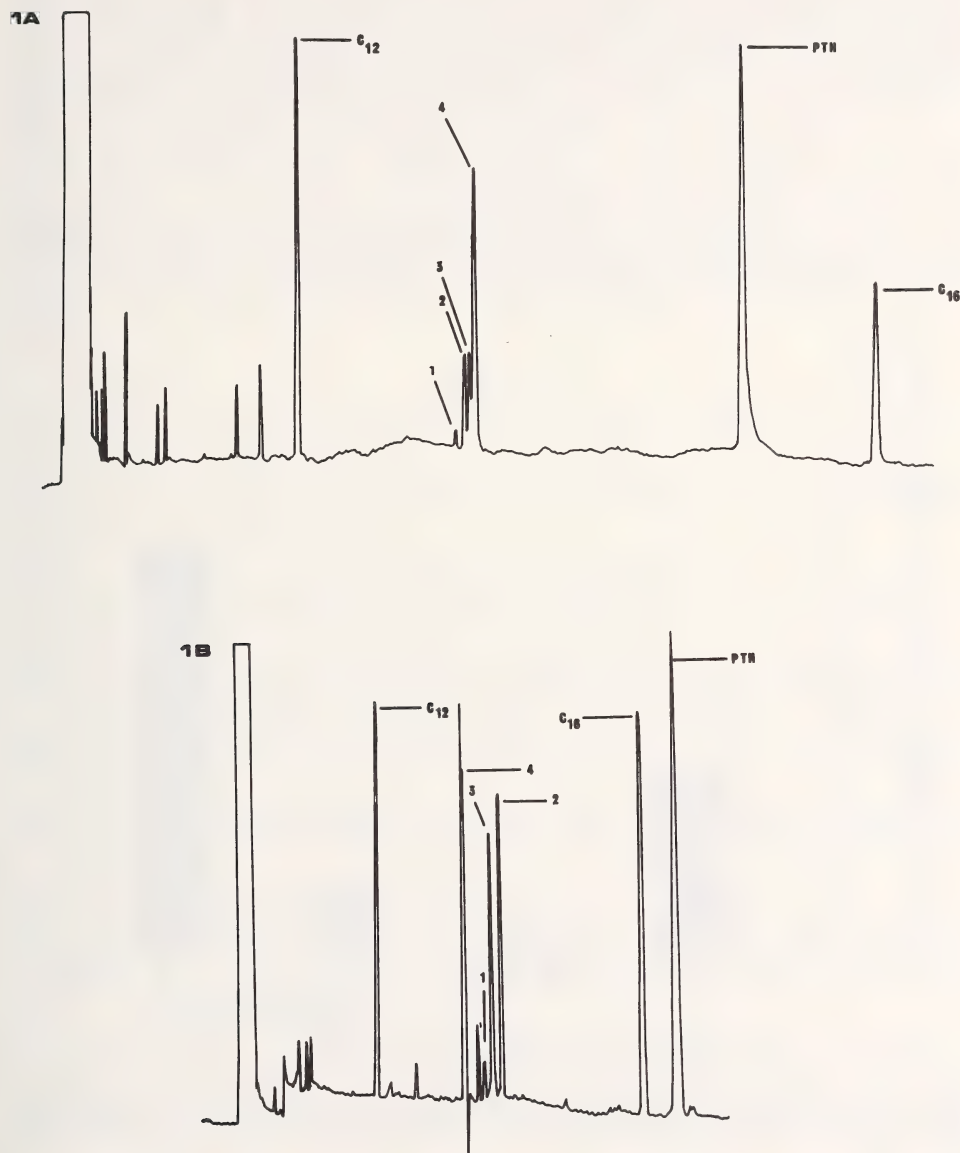


FIG. 1. A, Gas chromatographic analysis of 1 female equivalent on the methyl silicone column. 1 = Z9-14:Ac, 2 = E11-14:Ac, 3 = Z11-14:Ac, 4 = 14:Ac, C₁₂ = dodecan-1-ol acetate, C₁₆ = hexadecan-1-ol acetate, Pth = phthalate. B, Analysis on the BP 20 column, captions as in Fig. 1A.

GC-mass spectral analysis of the synthetic blend identified indicated that the 3 mono-unsaturated acetates were not resolved on the DB 5 column. However, they were resolved from 14:Ac. Analysis of the natural product samples indicated that 2 distinct peaks were present which had identical fragmentation patterns and retention times with 14:Ac and the mono-unsaturated peak. Analysis of the synthetic blend using the SBP1 column resulted in the separation and acquisition of full spectra (60-300 AMU) for all 4 compounds. Only 4 distinct peaks eluted from the natural product sample when injected onto this column and these peaks had retention volumes and fragmentation patterns identical to those of the synthetic standard. Therefore, the presence of Z9-14:Ac, E11-14:Ac and Z11-14:Ac in the extracts was confirmed.

Field studies were conducted using the 4-component blend and a 3-component blend that did not contain the minor component, Z9-14:Ac. The 4-component blend was a significantly better lure than were caged females (Fig. 2). Also the blend that did not contain the minor component Z9-14:Ac was significantly less effective than were females, and no more attractive than unbaited traps. This was not only reflected in the lower mean number of insects caught per night but also by the large variability in the numbers. Obviously, Z9-14:Ac is important in attracting males of the potato stem borer.

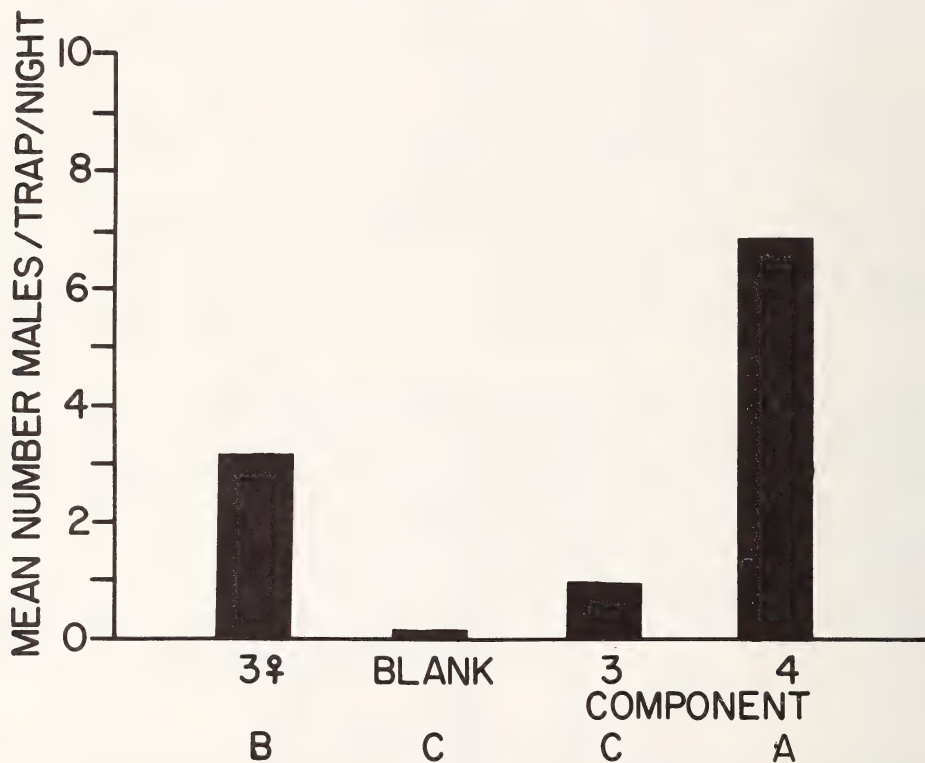


FIG. 2. Results of field trapping studies using the 3-component blend that did not contain Z9-14:Ac, the 4-component blend, and females. Means subtended by different letters are significantly different in a Duncan's multiple range test ($p < 0.05$).

Results of the two field tests were pooled (Fig. 2) because the two tests were not different (Duncan's multiple range test, $p < 0.05$). This probably indicates that the level of infestation was similar in each field. However, there was variability between trap positions with more males being captured at certain sites than at others when baited with either females

or the 4-component blend. These sites were close to the perimeters of the fields and near large areas of natural grass hosts.

The mean number of moths per night captured in the light trap was 2.1/night compared to 7.0 males in pheromone-baited traps. Although only 1 light trap was used, the numbers captured were similar to those reported by Deedat *et al.* (1983) during the latter half of August and early September. The pheromone traps were much more effective than was the light trap in monitoring the potato stem borer population. We are still analyzing the volatile pheromone blend released by calling females and assessing the behavioral function of each of the components in the reproductive sequence performed by males. However, the 4-component blend will be of considerable value in effectively monitoring this pest in individual fields at a fraction of the cost of monitoring by light traps.

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A REVISION OF EASTERN NORTH AMERICAN SPECIES OF *ATYLOTUS* (DIPTERA: TABANIDAE) WITH KEYS TO ADULT AND IMMATURE STAGES

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Abstract

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Adults of ten species of *Atylotus* from eastern North America, including three new ones (*palus*, *hyalica*, and *sphagnicola*), are described. Larvae and pupae of two of these are also described for the first time. The Holarctic distribution of *Atylotus sublunaticornis* (Zetterstedt) is recognized. *Atylotus pemeticus* (Johnson) is synonymized with *A. intermedius* Walker. Keys to adults of all 14 species of North American *Atylotus* and to larvae and pupae of 11 species are presented.

Introduction

Atylotus was first proposed as a subgenus of *Tabanus* by Osten Sacken (1876) who included two species, *bicolor* Wiedemann and *fulvescens* Walker. The latter species was synonymized under *bicolor* by Stone (1938). He also elevated *Atylotus* to generic ranking and included the additional North American species, *insuetus* Osten Sacken, *ohioensis* Hine, *pygmaeus* Williston, *pemeticus* Johnson and *thoracicus* Hine. (*Tabanus duplex* Walker, listed by Stone as unrecognized, is also now recognized as a species of *Atylotus* occurring widely in eastern North America). A year earlier, but apparently unknown to Stone, the uniqueness of *pygmaeus* had been recognized by Fairchild (1937), who made it the type species of *Microtabanus*, where it still stands. Subsequently, *utahensis* Rowe and Knowlton (1935) and *tingaureus* Philip (1936), which have variously been considered as varieties, subspecies or species related to *insuetus*, were added to the complement of the genus. Philip (1941) then synonymized *insuetus* and *Tabanus intermedius* Walker, another species which Stone listed as an unrecognized North American species, under *incisuralis* (Macquart). Pechuman (1981), having seen specimens from Michigan resembling the description of *intermedius*, examined the types of *intermedius* and *incisuralis* and confirmed that the former species occurs in North America and that the latter showed no close resemblance to any North American species. This has meant the reinstatement of *insuetus*. Pechuman also described in the same paper a new eastern North American species, *Atylotus woodi*, having frontal calli similar to *intermedius*, *insuetus*, *utahensis* and *tingaureus*. Teskey (1983) then described *Atylotus calcar*, a new western North American species that had previously been confused with *insuetus*, and provided further evidence confirming the specific status of *utahensis* and *tingaureus*.

The identity of those members of *Atylotus* having frontal calli are, therefore, now well established. The same cannot be said for the remaining members of the genus in North America lacking frontal calli. As the writer is currently preparing a manual to the Tabanidae of Canada and Alaska, it was deemed necessary to clarify at least some of the taxonomic problems associated with this group, thus the purpose of this study.

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Atylotus Osten Sacken

Atylotus Osten Sacken, Mem. Boston Soc. Nat. Hist. 2:426, 1876 (as subg. of *Tabanus*); type species *Tabanus bicolor* Wiedemann.

Ochrops Szilady, Ent. Mitt. 493, 1915; type species *Tabanus plebejus* Fallen.

Dasystypia Enderlein, Mitt. Zool. Mus. Berlin 10:347-348, 1922; type species *Tabanus rusticus* Linnaeus.

Female. Length 8-15 mm; of typical tabanine form. Eyes pilose, often with single transverse dark stripe in dried specimens; dorsal postocular fringe of hairs often distinct. Frons moderately dimensioned; height-basal width index 2.1 to 4.3, only moderately, if at all, widened above; basal and median denuded calli, when present, distinctly less than width of frons, usually no more than half the width. Ocelli, or their remnants, absent. Antenna yellow; scape and pedicel paler than flagellum, with yellow and black hair; basal flagellomere with obtuse dorsal angle and no more than shallow dorsal excavation. Second palpomere creamy-white, moderately swollen basally, tapered apically, with black and white hair usually uniformly mixed on lateral surface.

Thorax with dark integument, extensively to completely covered with whitish to brownish pruinosity, the former especially on pleural regions and coxae which are also almost exclusively white or yellow-haired; remaining leg segments predominantly yellow to orange with apex of fore tibia, fore tarsi and bases of mid and hind femora usually darkened. Halter yellow to orange, knob sometimes moderately darkened. Wing mostly hyaline; only costal, humeral, and stem cells¹ usually infuscated.

Abdomen with integument usually more or less yellow to orange laterally and with variable pattern of pale and dark hairs or completely pale-haired.

Male. Differs from female as follows: head holoptic; eye with upper median area, exclusive of narrow dorsal and lateral margin, with enlarged ommatidia; eye pilosity longer and denser; postocular fringe of hairs usually longer; basal flagellomere of antenna usually more slender; second palpomere oval; femora usually more extensively darkened; body hairs significantly longer and often arranged in quite different pattern on abdomen.

Mature larva. Distinguishable from all but a few species of *Tabanus* L. in having pubescent markings on median lateral surface of anal segment, and this segment and the terminal respiratory siphon each being no longer than their greatest diameter.

Pupa. Distinguishable also from all but a few species of *Tabanus* by the dorsal and lateral tubercles of terminal aster being inclined dorsoposteriorly on same plane, so that, in lateral view, dorsal tubercles hidden by laterals or lateral tubercles inclined more than dorsals.

¹Stem cell is based of basal cells (br and bm) and behind base of radius (stem vein of some writers). Other morphological terminology follows the Manual of Nearctic Diptera, Vol. 1, 1981.

KEY TO *ATYLOTUS* FEMALES

1. Frons with glossy basal and median calli, or only a basal callus, neither more than about half width of frons 2
Frons completely pruinose, without denuded calli 7
2. Body hairs almost completely white; black hairs only on antennae, palps, notopleural lobes and tibiae and tarsi. Costal cell concolorous with wing membrane elsewhere *utahensis* (Rowe and Knowlton)
Black hairs present additionally on frons and dorsum of thorax and abdomen. Costal cell color variable 3
3. Nearly lateral third of abdominal tergites orange and prominently outlining a median black stripe *woodi* Pechuman
Abdomen not as broadly orange laterally 4
4. Pale hairs on at least scutum and abdomen distinctly yellow 5
Pale hairs on all parts of body white to creamy-white 6
5. Thoracic pleural hairs yellow. Postocular fringe of hairs long (0.25 mm) and black *tingaureus* (Philip)
Thoracic pleural hairs white. Postocular fringe of hairs relatively short (0.125 mm) and including many white hairs *intermedius* (Walker) (in part)
6. Abdominal coloration in unrubbed specimens greyish as a result of larger median and sublateral white-haired patches on each tergite. Fork of R 4+5 usually with long spur vein. Apical flagellomeres darker than basal flagellomere *calcar* Teskey
Abdominal coloration dominantly black with little evidence of median and sublateral paler areas on tergites. Fork of R 4+5 with no more than short spur vein. Flagellum usually uniformly yellow *insuetus* (Osten Sacken)
7. Pleural hairs bright yellow; basal flagellomere about as broad as long *bicolor* (Wiedemann)
Pleural hairs white; basal flagellomere usually longer than broad 8
8. Pale hairs on scutum and abdomen white and concolorous with thoracic pleural hairs 9
Pale hairs of scutum and / or abdomen, or calypteral hair tuft, at least faintly yellow and contrasting with white thoracic pleural hairs 10
9. Postocular fringe of hairs mostly black *sublunaticornis* (Zett.)
Postocular fringe of hairs white *ohioensis* (Hine)
10. Scutum and dorsum of abdomen completely pale-haired or with sparse black hairs; rather sparse black hairs on palps and notopleural lobe *thoracicus* (Hine)
Rather prominent black hair on scutum, dorsum of abdomen, palps and notopleural lobe 11
11. Costal and humeral cells hyaline; notopleural lobe yellow; postocular fringe usually extensively yellow *hyalicosta* n.sp.
Costal and humeral cells tinted and contrasting with hyaline membrane elsewhere, postocular fringe usually predominantly black 12
12. Abdominal tergites 2 to 4 entirely black-haired medially with at most a caudal fringe of yellow hairs. Upper surface of veins R1, Sc and C with extensively yellow setae *dulx* (Walker)
Abdominal tergites 2 to 4 with yellow hairs medially, either generally mixed with black hairs or forming rather distinctive patches of dominant yellow hair. Upper surface of anterior wing veins usually with predominantly black setae 13
13. Abdominal tergites 2 to 4, or 5 with discrete median triangles of bright yellow hairs based posteriorly, and flanked on either side by submedian anterior patches of exclusively black hair, the pattern visible to the naked eye *palus* n.sp.
Pale hairs on tergites not bright yellow and not arranged in distinct median triangles, but rather generally mixed with black hairs medially 14

14. Length 12 mm or more *intermedius* (Walker) (in part)
 Length rarely more than 11 mm *sphagnicolus* n.sp.

KEY TO *ATYLOTUS* MALES

1. Postocular fringe of hairs short, little if any longer than eye hairs 2
 Postocular fringe of hairs much longer than eye hairs 5
2. Body hairs, especially on abdomen, almost completely white; sparse black hairs only on antenna, palp, notopleural lobe, scutum, tibia and tarsus
 *utahensis* (Rowe and Knowlton)
 Pale body hairs not necessarily white, and black hairs more abundant and present additionally on frons and abdominal tergites 3
3. About lateral third of first six abdominal tergites orange, and providing sharp margin to median black stripe. Legs almost entirely orange *woodi* Pechuman
 Orange markings on sides of abdomen much less extensive, or in the form of sublateral spots, especially on tergites 3 and 4, and usually not sharply outlining median black area. Femora extensively blackened 4
4. Fork of R 4+5 with long spur vein. Terminal flagellomeres black and contrasting with orange basal flagellomere *calcar* Teskey
 Fork of R 4+5 with no more than very short spur vein, but usually lacking. Terminal and basal flagellomeres usually concolorous *insuetus* (Osten Sacken)
5. Thoracic pleural hairs at least partially yellow 6
 Thoracic pleural hairs completely white 9
6. Almost all body hairs yellow, including wing setae and postocular fringe
 *bicolor* (Wiedemann)
 Abundant black hair in postocular fringe and mixed with pale hairs on scutum and abdominal tergites 7
7. All pleural hairs more or less yellow; sides of abdominal tergites at most very narrowly orange. Western species *tingaureus* (Philip)
 Only those hairs on mesanepisternum and sometimes laterotergite yellow, remainder white; about lateral one quarter of tergites 1 to 3 orange. Eastern species .. 8
8. Flagellum of antenna about four times as long as greatest width of basal flagellomere; latter with distinct dorsal excision. Eye hairs about 0.125 mm long. Length of body 12-13 mm *intermedius* (Walker)
 Flagellum of antenna about three times as long as greatest width of basal flagellomere; latter without dorsal excision. Eye hairs about 0.08 mm long. Length of body 10-11 mm *palus* n.sp.
9. All pale hairs on body white and concolorous with thoracic pleural hairs 10
 Pale hairs on scutum and abdomen yellowish and contrasting with white thoracic pleural hairs 11
10. Almost all body hairs white; black hairs restricted to legs, notopleural lobes and palps
 *ohioensis* (Hine)
 Black hairs abundant on most areas of body *sublunaticornis* (Zett.)
11. Postocular fringe of hairs predominantly yellow 12
 Postocular fringe of hairs predominantly black 13
12. Costal, humeral and stem cells hyaline. Notopleural lobe yellow or paler than scutum.
 Wing veins C and R1 with abundant black setae *hyalicosta* n.sp.
 Costal, humeral and stem cells infuscated. Notopleural lobe as dark as scutum. Wing veins C and R1 with only yellow setae *duplex* (Walker)
13. Yellow hairs dominant on scutum and dorsally on abdomen, black hairs inconspicuous on these areas and also relatively sparse on notopleural lobe and palps
 *thoracicus* (Hine)
 Black hair abundant on palp, scutum, notopleural lobe and dorsally on abdomen
 *sphagnicolus* n.sp.

KEY TO *ATYLOTUS* LARVAE

Larvae and pupae of *Atylotus* are not distinguishable as a group from all species of *Tabanus*. To maintain emphasis on this close similarity it is preferable to present the following keys as modifications to the keys to larvae and pupae of *Tabanus* and *Atylotus* given by Teskey (1969). The lead couplet number is the same in both keys. A number in brackets after a couplet number is that couplet in the 1969 key that leads to this place. Names or letter designations in brackets before the species names are the identifications applied to these taxa in the 1969 publication.

- 17 (16). Prothoracic anterior pubescent annulus lacking lateral caudal projections. Pubescence absent from anterior margin of meso- and metathorax or faintly evident only laterally on metathorax 18
Prothoracic anterior pubescent annulus with slender paired lateral caudal projections. Anterior margins of meso- and metathorax with pubescent annuli 19
18. Anal segment with median lateral pubescent patches above but separate from, the pubescence on the anal ridges (Fig. 3) *A. palus* n.sp.
Anal segment lacking median lateral pubescent patches above the pubescence clothing the anal ridges (duplex) *A. sublunaticornis* (Zett.)
19. Posterior pubescence encircles preanal segment. Usually three small pubescent spots on each lateral surface of anal segment *A. bicolor* (Wied.)
Posterior pubescence narrowly absent laterally on preanal segment. Normally only two small pubescent patches on each lateral surface of anal segment (sp. A) *A. hyalicausta* n.sp.
20. (10). Anterior pubescence encircles meso- and metathorax 21
Anterior pubescence on meso- and metathorax interrupted dorsally and ventrally (sp. C.) *A. woodi*
Pechuman (eastern N.A.) and *A. insuetus* (Osten Sacken) (western N.A.)
21. Midlateral caudal projection from median pubescent figure on anal segment united with posterior annulus 22
Midlateral caudal projection from median pubescent figure on anal segment not reaching posterior annulus 23
22. Lateral pubescent projections from anterior annuli on meso- and metathorax extending caudally $\frac{2}{3}$ and $\frac{1}{2}$ length of segments respectively.
Anterior and pseudopodial pubescence separated laterally and ventrally. Mature larva about 20 mm long *A. calcar* Teskey
Lateral pubescent projections from anterior annuli on meso- and metathorax extending caudally $\frac{1}{2}$ and $\frac{1}{3}$ lengths of segments respectively.
Anterior and pseudopodial pubescence running together laterally and ventrally. Mature larva 12-15 mm long *Tabanus sparus* Whitney
23. Anal segment and respiratory siphon slightly longer than their greatest diameters. Each tracheal trunk approximately 0.6 mm in diameter in preanal segment and tapering abruptly near first abdominal segment. Saltmarsh species *Tabanus nigrovittatus* Macquart
Anal segment appearing swollen, length of it and of respiratory siphon equal to or shorter than their greatest diameters. Each tracheal trunk not over 0.4 mm in diameter in preanal segment and tapering gradually anteriorly. Fresh water species 24
24. Posterior pubescence present on last five to seven segments and encircling the last three to five segments 25
25. Posterior pubescence present on no more than last four segments and usually encircling the last two segments 27
Prothoracic anterior pubescent annuli with lateral caudal projections expanded apically. Pubescence elsewhere moderately dark 26
Prothoracic anterior pubescent annuli with lateral caudal projections slender and tapered apically *A. thoracicus* (Hine)

26. Posterior pubescence present on segments 5 to 11, and encircling last five segments.
Dorsolateral extension of pubescence from anal ridges narrowly connected ventro-
laterally to posterior pubescence on segment 10 (Fig. 4) *A. sphagnicolus* n.sp.
Posterior pubescence present on segments 7 to 11, and encircling the last four segments.
Dorsolateral extension of pubescence from anal ridges not connected to posterior
pubescence on segment 10 *A. ohioensis* Hine
27. Striations absent from entire dorsal and ventral surfaces of thoracic segments. Anterior
and pseudopodial pubescence connected only ventrolaterally on first 4 or 5
abdominal segments. Larvae normally inhabit damp semiarable soils
..... *Tabanus quinquevittatus* Wied.
Striations absent only from dorsal and ventral discal surfaces of thoracic segments.
Anterior and pseudopodial pubescence connected both dorsolaterally and ventro-
laterally on first 6 segments (pematicus) - *A. duplex* (Walker)

KEY TO ATYLOTUS PUPAE

18. (1). Fringe spines absent from lateral third to half of second abdominal sternite . . 19
Fringe of spines nearly or completely traversing second abdominal sternite 23
19. Integument of nearly uniform color 20
Portions of head and dorsum of thorax distinctly darker than other areas 21
20. Thoracic spiracles at least 0.5 mm long. Antennal ridges prominent and elevated about
0.15 mm above median cleft *A. bicolor* (Wiedemann)
Thoracic spiracles no longer than 0.4 mm. Antennal ridges represented by a low rugose
area elevated no more than 0.05 mm *A. thoracicus* (Hine)
21. Antennal ridges in form of areas of weak rugosity. Abdominal fringe spines on posterior
tergites showing almost no differentiation into anterior and posterior series either
in relative length or spatial separation *A. sphagnicolus* n.sp.
Antennal ridges well developed, with distinct crest. Abdominal fringes on posterior
tergites with longer spines posteriorly in fringes and shorter spines anteriorly
..... 22
22. Pupa 16 to 19 mm long (sp. A) *A. hyalica* n.sp.
Pupa 14 to 16 mm long (pematicus) *A. duplex* (Walker)
23. Thoracic spiracles no longer than 0.5 mm and spiracular prominences not exceeding
anterior dorsal margin of thorax 24
Thoracic spiracles 0.6-0.8 mm long and spiracular prominences exceeding anterior dorsal
margin of thorax by about 0.2 mm
..... *Tabanus similis* Macquart, *T. lineola* Fabricius
24. Fringes of spines, especially on more posterior abdominal segments, distinctly differen-
tiated into two series by angle of incline of spines, those posteriorly in each fringe
reclining posteriorly and those spines more anterior in fringe erect, the two series
usually well spaced 25
Spines in fringes on more posterior abdominal segments all projecting at about the same
angle 27
25. Pupal integument almost uniformly pale yellowish brown. Antennal and frontal ridges,
or the areas they normally occupy, of about equal elevation and
prominence 26
Portions of head, and dorsum of thorax darker than remainder of integument
..... *A. insuetus* (Osten Sacken)
26. Thoracic spiracles 0.3 mm long (duplex) *A. sublunaticornis* (Zett.)
Thoracic spiracles 0.4-0.5 mm long (sp.C) *A. woodi* Pechuman
27. Pupa no longer than 16 mm. Thoracic spiracles 0.3-0.4 mm long
..... *A. palus* n.sp., *A. ohioensis* (Hine)
Pupa about 20 mm long. Thoracic spiracles at least 0.5 mm long . . *A. calcar* Teskey

Atylotus bicolor (Wiedemann)

Tabanus bicolor Wiedemann 1821:46

Tabanus fulvescens Walker 1848:171

Tabanus ruficeps Macquart 1855:55

Female. Length 8 - 11 mm. Head integument predominantly yellow to light brown pruinose with black and yellow hair on frons, mostly yellow-haired elsewhere, except postocular fringe sometimes with sparse black hair. Frons 2.9-3.6 times as long as basal width, usually slightly widened above. Antenna yellow, scape and often pedicel with black hair mixed with the yellow; basal flagellomere nearly as wide as long, with at most only shallow dorsal excision, longer than terminal flagellomeres. Second palpomere yellow, with yellow and black hairs; moderately swollen basally (2.5 - 3.1 times as long as greatest diameter). Eye sometimes with partial to nearly complete dark transverse stripe.

Thorax mostly dark brown pruinose on scutum, with erect black hairs and more recumbent yellow hairs; notopleural and postpronotal lobes yellow, former with yellow and black hair; pleura greyish puinose with yellow hair concolorous to that on other parts of body. Legs, except sometimes parts of mid and hind coxae yellow, mostly yellow-haired, with black hairs predominantly on tibia and tarsi. Wing with costal, humeral and stem cells almost hyaline to distinctly yellowish infuscated; anterior wing veins with yellow setae. Halter yellow.

Abdomen dorsally predominantly dark brown with sides of first 3 to 6 tergites distinctly more yellow; sternites mostly yellow; hairing of tergites yellow and black, yellow hairs uniformly distributed, black hair confined more to middle of tergites, especially on tergite 2; sternites completely yellow-haired.

Male. Apart from usual sexual differences, differs from female as follows: postocular fringe of longer yellow hairs; antenna and palpi frequently without black hair; thorax with long yellow hairs on scutum, black hairs inconspicuous; legs with yellow hair more dominant on distal segments; abdomen more broadly yellow laterally, with dark brownish median stripe widest anteriorly and usually no more than one-third the width of abdomen.

Mature larva and pupa. Described by Teskey (1969).

Specimens examined. 81♀♀, 91♂♂ (not including types) from localities plotted in Fig. 1.

Remarks. Adults of this species are distinctive from other *Atylotus* by all pale hairs, including those on the pleural surfaces of the thorax being yellow.

Atylotus duplex (Walker)

Atylotus pemeticus of some authors, not Johnson.

Tabanus duplex Walker, 1854:173 (new name for *imitans* Walker).

Tabanus imitans Walker, 1848:173 (preocc., Walker, 1848:146).

Female. Length 9-12 mm. Predominantly dark brown or black. Eye very sparsely, short pilose, yellow brown to reddish in dried specimens, usually lacking any vestige of a transverse stripe. Postocular fringe of hairs usually extensively black, rarely completely yellow. Frons, subcallus and upper parts of genae yellow to tawny pruinose; the former with yellow and sparse black hair; sides of subcallus with few hairs; genae and clypeus usually with pale hairs only; underlying integument, except medially on frons, yellow; frons 3.4-4.0 times as long as basal width, nearly parallel-sided. Basal flagellomere 1.1-1.4 times as long as greatest width, with obtuse dorsal angle and usually slight dorsal excavation; apical flagellomeres about as long as width of basal flagellomere. Second palpomere 2.1-3.0 times as long as greatest width.

Thorax black with white pruinosity and white hairs on pleura and coxae and faintly brownish pruinosity with recumbent yellow hairs and more erect black hairs on scutum and scutellum. Legs except coxae, mostly orange with base of mid and hind femora often darkened. Wing with costal, humeral, and usually stem cells tinted; setae dorsally on C, Sc, R1 and basicosta usually predominantly yellow; calypteral tuft of hairs yellow. Halter yellowish-orange.

Abdomen dorsally mostly dark brown with lateral quarter or less of first two tergites and narrow lateral margins of remaining tergites yellowish; these areas mostly with concolorous hairs, except that caudal margins of tergites with fringe of yellow hairs, which medially may encroach sparsely into middle of tergites, while black hairs may extend laterally onto yellow sides of tergite 2. Sternites dark with greyish pruinosity and yellow hairs except for a few black hairs on caudal segments.

Male. Apart from usual sexual differences, the most dimorphic of any species of the genus; postocular fringe of long completely yellow hairs; thoracic hairing longer, predominantly yellow on scutum, with black hairs most distinct on notopleural lobes; wing with anterior vein setation completely yellow; abdomen with integument of as much as lateral $\frac{1}{2}$ to $\frac{2}{3}$ of anterior tergites yellow; tergites predominantly long yellow-haired, with black hairs rather inconspicuous medially; sternites usually yellowish-orange laterally.

Mature larva and pupa. Described by Teskey (1969) under the name of *pematicus*. These larvae were found in wet moss in woodland swamps and spring-fed drainage beds.

Specimens examined. 110 ♀♀, 64 ♂♂, including the lectotype ♀ and paralectotype ♂ from St. Martins Falls, Albany River, Hudsons Bay, Canada. The distribution of these are plotted on Fig (2).

Comments. Females of this species are quite variable, especially in the color of the postocular fringe of hairs and vein setae and the occasional presence of a well developed eye stripe. Since no concordance has been detected in such variations, they are judged to be of an intraspecific nature. However, this reduces the characteristics for reliable identification to only the hair color pattern on the abdominal tergites.

Males, on the other hand, are relatively uniform in appearance and are quite dimorphic to the females by virtue of their completely yellow postocular fringe and predominantly yellow scutal and abdominal hairs.

The association of sexes which was first made by Walker in selecting his type specimens was confirmed by my rearings. The males are very similar to *hyalicosta* n.sp., differing only in the yellowish costal cell. None have a yellow notopleural lobe as do most males of *hyalicosta*. At the same time, the yellow hairs of the postocular fringe of the male, coupled with the predominantly yellow abdominal tergal hairing and yellow anterior vein setae, clearly negates any conspecificity with other species.

Atylotus palus n.sp.

Female. Length of body 9-11 mm, of wing 7.5-9.5 mm. Eye in dried specimens lacking transverse stripe, very sparsely short pilose. Frons 2.8-3.4 times as long as basal width, parallel-sided to slightly widened above, with underlying integument predominantly dark, covered with grey and brown pruinosity and with yellow and black hair. Vertex and median occipital sclerites usually similarly colored. Postocular fringe of mixed yellow and black hairs. Subcallus with yellow integument covered with yellow pruinosity. Clypeus and gena with predominantly dark integument covered by greyish to brown pruinosity and mainly yellow hairs, with a few black hairs on upper part of gena. Antenna with basal flagellomere $\frac{1}{3}$ to $\frac{1}{2}$ longer than greatest width with obtuse dorsal angle and little or no dorsal excavation; apical flagellomeres about as long as greatest width of basal flagellomere. Second palpomere creamy-

white, 2.1-2.6 times as long as greatest diameter, tapering to acute point, with slight subapical constriction and predominantly black hair.

Thorax, including coxae, with black integument, overlaid on pleura and coxae with whitish pruinosity and white hairs; scutum with brownish pruinosity and bright yellow recumbent hairs and sparser more erect black hairs. Legs mostly yellow to orange with bases of mid and hind femora, apex of fore tibia, and fore tarsi darkened. Wing membrane hyaline except for yellowing of costal, humeral, and stem cells; C_1 , Sc and R_1 with predominantly black setae, yellow setae confined to anterior margin of C . Calypteral hair tuft yellow. Halter orange.

Abdominal ground color predominantly brownish-black but often with lateral $\frac{1}{4}$ to $\frac{1}{3}$ of first two or three tergites more or less distinctly yellow; all tergites usually with bright yellow and black hair in a fairly consistent pattern, with yellow hair generally dominant laterally, on posterior margins, and in median, posteriorly based, triangles nearly or quite crossing tergites; black hair forming submedian anterior inverted triangles bordering the median ones, with some mixing of hair colors sublaterally. Some specimens with tergites almost completely yellow-haired. Sternites almost completely pale yellow-haired with some sparse, erect black hair on terminal segments.

Male. Apart from normal sexual differences, differing from female in having predominantly black or orange-tinted postocular fringe with yellow hairs largely confined to central ocellar tubercle area. Eye hairs less dense than in other species and no more than 0.1 mm long. Mesanepisternum and sometimes laterotergite with conspicuous yellow hairs. Black hair on abdominal tergites generally distributed and dominant over all except extreme lateral and posterior margins of tergites, which are exclusively yellow-haired, but mixed with yellow hair on sublateral areas of yellow integument and in median triangular intrusions of sparse yellow hair toward middle of tergites from posterior marginal yellow hair fringes.

Mature larva (Fig. 3). Creamy-white, approximately 18 mm long. Head capsule 1.9-3.4 mm long. Tracheal trunks slender. Anal segment subspherical, about as long as greatest diameter. Respiratory siphon length about equal to basal diameter. Integumental striations moderately prominent on all aspects of body except dorsal and ventral discal surfaces of thoracic segments. Pubescence present on all but mesothorax and usually metathorax. Anterior pubescence encircles prothorax and first four to six abdominal segments but absent laterally on abdominal segment 7 and usually on preceding two segments; metathorax sometimes with faint pubescence antero-laterally. Pseudopodial pubescence encircles first six abdominal segments; usually absent between dorsal and lateral pseudopodia on seventh abdominal segment; distinctly united with anterior pubescence only ventrolaterally, the two areas of pubescence only closely approaching a union dorsolaterally. Posterior pubescence narrowly encircles anal and preanal segments and restricted to dorsal and sometimes ventrolateral posterior margin of abdominal segment 6. Anal segment additionally with small, usually isolated, patches of pubescence midlaterally and dorsolaterally above short upward extension of pubescence on anal ridges; latter sometimes narrowly meeting midlateral spot.

Pupa. Length 24-25 mm. Empty exuvium almost brown with only the intersegmental membrane of abdominal segments showing slight contrast in colortone. Antennal ridges relatively prominent, rounded on leading edge, elevated about 0.10 mm above median cleft. Frontal tubercles in form of several low corrugated ridges between outer extremities of antennal ridges. Callus tubercles elevated about 0.1 mm. Thoracic spiracles 0.3 mm long, gently bowed; spiracular prominence not exceeding anterior margin of thorax. Abdominal fringes of spines traversing usual sclerites, uniseriate on all sternites except sternite 7 and anterior one or two pleurites and tergites, more or less distinctly biseriate elsewhere with distinction being as much in length of spines as in spatial separation; spines anteriorly in fringes generally shorter than more posterior spines, and spines of both series projecting at same angle. Fringe of tergum

7 with 40-55 spines, longest approximately 0.6 mm. Dorsal, lateral and ventral tubercles of aster about 0.25, 0.5 and 0.2 mm respectively; former two pairs inclined dorsoposteriorly on the same plane.

Type Specimens. Holotype ♀, Highland Rd., Mi. 15, Victoria Co., Nova Scotia, 23-28-VII-1978, G.B. Fairchild (trap in grassy bog). Deposited in Florida State Collection of Arthropods (F.S.C.A.); allotype ♂, same data except 27.VII-1.VIII.78; Paratypes 59 ♀♀, 13 ♂♂, including 18 ♀♀ and 5 ♂♂ from type locality, from localities plotted on Fig 5. One of these locations, Puslinch, Ontario, yielded larvae from which 2 ♀♀ and 4 ♂♂ were reared. This locality, an alkaline or marl bog, was described by Teskey (1969) in connection with his description of the immature stages of *Atylotus* sp. C.

Paratypes are deposited in Univ. Fla., C.N.C., Cornell Univ., M.C.Z., Nova Scotia Prov. Mus., Univ. Kansas and personal collection of A.W. Thomas.

The specific name is the latin word for marsh, bog, fen and swamp, of which the term "fen", as defined by Tarnocai (1980) fits the larval habitat most closely.

Comments. Larvae of this species closely resemble those of *A. sublunaticornis* (Zett.) which were described and illustrated by Teskey (1969) under the name of *duplex*. These two are the only known *Atylotus* species lacking complete anterior pubescent annuli on the meso and metathorax. The larva of this species differs from that of *sublunaticornis* in having pubescent markings on the median lateral surfaces of the anal segment and on the posterior of abdominal segment 6.

Pupae of *palus* will run to couplet 21 in the key provided in the above publication but exhibit only one of the two characters of each of the two species exiting there. Of these two, *thoracicus* and sp. A, greatest similarity is with the latter, here described and named *A. hyalicosta*. Possibly the only significant difference is the greater length of *hyalicosta*, at 16-19 mm, and its larger antennal ridges.

Adults, especially females, resemble *A. sphagnicolus* n.sp., some so closely that a question of their conspecificity might be considered. However, the consistent difference in the length of the eye hairs and color of the mesanepisternal hairs of males and the very great differences in the immature stages should dispel this possibility. Additionally, the preferred breeding sites of the two species are quite different, this species apparently restricted to neutral or alkaline wetlands while *sphagnicolus* appears to be partial to sphagnum bogs.

Most females of *palus* can be distinguished by the brighter yellow abdominal hairs and the more distinctive median triangles of yellow hair on the tergites.

Atylotus hyalicosta n.sp.

Female. Length 10-12 mm. Eye with narrow transverse reddish-brown stripe in dried specimens; postocular fringe of hairs usually predominantly yellow. Frons 3.2-4.1 times as long as basal width, nearly parallel-sided; underlying integument with blackish median elliptical area bordered by yellowish integument, with the whole covered by brownish pruinosity and short inconspicuous yellow and black hair. Subcallus yellowish, pruinose. Antenna with basal flagellomere 1.1 to 1.5 times as long as greatest width with, obtuse dorsal angle and no dorsal incision. Clypeus and genae mostly white pruinose, white-haired, except upper part of genae brownish-tinged. Second palpomere pale yellow 2.0-3.5 times as long as greatest width, predominantly black-haired.

Thorax blackish except for yellow to reddish notopleural and supraalar lobes; scutum and scutellum with recumbent orange to pale yellow hairs and erect black hairs, latter most conspicuous on notopleural lobes; pleura, and coxae whitish pruinose, white-haired. Legs

mostly yellowish-orange to pale brown. Halter yellow. Wing membrane, including costal cell, hyaline; calypteral hair tuft usually white. Setae on anterior wing veins usually predominantly black, occasionally mostly yellow.

Abdomen dorsally mostly dark-brown to black with sides of tergites more or less yellow, this yellowing most extensive on tergite 2 and sometimes comprising two-thirds width of segment but reduced on preceding and following tergites; yellow hair exclusively present on lateral and caudal margins and sometimes nearly evenly mixed with black hairs anteromedially, or black hairs dominant in latter areas. Sternites predominantly to completely black in ground color and white-haired, except for sparse black hair on sternites 6 or 7.

Male. Apart from usual sexual differences, differs from female as follows: postocular fringe of hairs long, mostly white to yellow, occasionally a bronze color; pale hairs on scutum and abdomen usually yellow to off-white but sometimes as white as pleural hairs; notopleural lobe sometimes dark; black hair almost absent on scutum and often very sparse on abdomen. Setae on anterior wing veins predominantly to completely yellow.

Mature larva and pupa. Described as *Atylotus* sp. A by Teskey (1969).

Type Specimens. Holotype ♀, Capreol, Ontario. 3.III.64, H.J. Teskey, specimen reared (No. 63-11-2) with associated larval and pupal exuvia; Canadian National Collection No. 18146. Allotype ♂ with same data but 25.VI.63 and also reared (No. 63-11-2); paratypes 82 ♀♀, 69 ♂♂ from localities plotted on Fig. (6). Paratypes deposited in C.N.C.; Cornell Univ., Florida S.C.A., U.S.N.M., M.C.Z., Cal. Acad. and Universities of Mich., Minn., Montreal, Kansas, Ohio S., W. Virginia and the personal collection of Dr. A.W. Thomas.

Comments. This is another rather variable species in integumental and hair coloring. This variation is seen in reared specimens even from the same locality. The most distinctive diagnostic features are the yellowish notopleural lobe and hyaline costal cell. One feature or both alone, or preferably combined with predominantly pale postocular hairs, some trace of an eye stripe, and the presence of some yellow hairs on all aspects of the abdominal tergites, will usually provide a reliable identification.

The dark abdominal hairing was seen only in some western Canadian material, including specimens from Alberta that were reared by Dr. A.W. Thomas. That this is merely intraspecific variation seems assured since the adults and immature stages conform closely in all other respects.

Atylotus intermedius (Walker)

Tabanus intermedius Walker, 1848:173.

Tabanus incisuralis of some authors, not Macquart, in reference to eastern N.A. specimens.

Tabanus pemeticus Johnson, 1921:11 new synonymy.

Female. Length 14 mm. Eye orange-brown when dried, with transverse narrow reddish stripe from inner angle extending $\frac{1}{2}$ to $\frac{2}{3}$ width of eye; sparsely short pilose. Postocular fringe of hairs short, predominantly yellow. Frons 3.6 times as long as basal width, parallel-sided; mostly black covered by greyish to brown pruinosity and yellow and black hair, sometimes with subspherical, denuded brownish basal callus being less than half width of frons, and ragged linear black median callus. Subcallus yellowish-brown, pruinose. Clypeus and gena mainly black in ground color, covered with white pruinosity, brownish tinged on upper margin of genae and mostly white-haired. Antenna with scape and pedicel yellow with black and yellow hairs, flagellum orange; basal flagellomere 1.6 times as long as broad, with obtuse dorsal angle and very shallow dorsal excavation; terminal flagellomeres almost as long as basal flagellomere. Second palpomere creamy-white with black and white hair, 2.5 times longer than basal width, concavely tapered apically.

Scutum and scutellum mainly black, notopleural lobe and postalar and supra-alar lobes more or less orange, with yellowish recumbent hairs dominant over sparse, erect, black hairs, except on notopleural lobes. Pleura and coxae black, covered with white pruinosity and completely white-haired; remainder of legs mostly orange. Halter orange. Wing with costal cell yellow; furcation of R 4+5 with short spur vein; setae on anterior wing veins predominantly black; calypter hair tuft yellow.

Abdomen dorsally greyish-brown pruinose over mostly dark integument, only posterolateral corner of tergum 1 and narrow reflexed sides of other tergites yellow; tergite 1 with predominantly yellow hair concentrated laterally, on posterior margins, and in median triangles that narrow anteriorly, with black hairs dominant elsewhere, but with much inter-mixing along adjacent margins, making distributional patterns vague. Sternites greyish pruinose with predominantly yellowish-white hairs and sparse black hairs medially.

Male. Similar to female except for sexual differences and: postocular fringe with long yellow and black hairs and ocellar tubercle predominantly yellow-haired. Second palpomere suboval, pointed apically, yellowish, with yellow and black hairs. Genae completely yellow-haired. Scutum with long, predominantly yellowish hairs; pleura with long white hairs, except hair tufts on anepisternum and laterotergite yellowish. Legs with bases of femora dark brown to black. Abdominal tergites more broadly yellowish laterally, and dominantly yellow haired laterally and on posterior margins, but black and white hairs mixed elsewhere.

Immature stages. Unknown

Specimens examined. ONTARIO: Lectotype ♀ and paralectotype ♂, St. Martins Falls, Albany River (in B.M.N.H.); 1 ♀ Rushing River Prov. Pk., Kenora, 11-VIII.70, J.R. Powers; 1 ♂, Low Bush, Lake Abitibi, 17.VIII.23, N.K. Bigelow; MICHIGAN: 1 ♀ 1 ♂, Chippewa Co., 3 mi. W. junc. M28, 18.VIII.75, C.T. Maier; MAINE: 1 ♀, Spectacle Mt., Gilead, 31.VII.36; 1 ♀ Ship Harbor, Mt. Desert Isl., 20.VII.56, F.R. Shaw; 1 ♀, F.A. Eddy (no other data); holotype ♀, allotype, and paratype ♀ of *Atylotus pemeticus* (Johnson) respectively: Southwest Harbor, 20.VIII.20, C.W. Johnson; Northwest Harbor, 22.VIII.18, C.S. Minot; Mt. Cadillac, Mt. Desert, 17.VIII.20, C.W. Johnson.

Comments. The minimum length of the above specimens is 12 mm. No specimens of other eastern species of *Atylotus* studies here exceed this size and few reach it. Thus the 13-14 mm length of the type specimens of *A. pemeticus* coupled with their close similarity in almost all other features strongly supports the synonymy with *A. intermedius*. The only difference in the two is the absence of basal and median calli in the holotype of *pemeticus*. The Mt. Desert paratype of *pemeticus* and other Maine specimens listed above have very small basal calli with ragged uneven edges and, in one specimen, with pruinosity extending into the middle of the callus, suggesting that the denudation is a product of abrasion. Similar evidence for the origin of the median callus can also be seen. That both forms occur on Mt. Desert Island, Maine and have a common flight period is also indicative of their conspecificity.

Atylotus sublunaticornis (Zetterstedt)

Tabanus sublunaticornis Zetterstedt, 1842:118.

Tabanus plebejus of some authors, not Fallen, 1817.

Baikalia vaillanti Surcouf, 1921:39.

Female. Length 9-12 mm. Predominantly black integument with white and black hairs. Eyes short pilose, usually with vestige of single transverse eye stripe in dried specimen. Frons 2.3 to 3.1 times as long as basal width, essentially parallel-sided, dark with areas of white and slightly brown pruinosity, and black and white hairs, former more abundant dorsally. Postocular fringe of hairs black. Subcallus with underlying integument more or less yellow.

Clypeus and genae whitish pruinose with white and black hairs, latter more abundant on genae. Antenna with basal flagellomere $\frac{2}{3}$ to $\frac{3}{4}$ as wide as long, with obtuse dorsal angle and little or no dorsal excavation; terminal flagellomeres equal to, or longer than greatest width of basal flagellomere. Second palpomere 2.2 to 3.2 times as long as greatest diameter, evenly tapered or acuminate apically.

Thorax and coxae white pruinose; scutum and scutellum with more or less recumbent white hair and erect black hair; pleura and coxae with longer erect white hair; remaining leg segments yellow, darkening at apex of fore tibia and tarsus and on base of mid and hind femora, with mostly black hair except on mid and hind femora. Wing with calypteral hair tuft white; wing membrane hyaline; anterior vein setae exclusively black. Halter stem yellow with knob brownish.

Abdomen dark, with sides of tergites narrowly yellow, more extensively so on sides of tergites 1 and 2; tergites with black and white hair, white hair on tergites confined to lateral margins, and posterior marginal fringes with sublateral patches of white hair intruding from margin into middle of tergites, latter especially evident on tergites 2 and 3; sternites with mostly white hair and only a few sparse long black hair medially.

Male. Apart from usual sexual differences, differing from female as follows: abdominal tergites usually more broadly yellow laterally, with this color sometimes extending to tergite 4; white hairing on tergites often more extensive covering lateral third of tergites.

Mature larva and pupa. Described and illustrated by Teskey (1969) under the name of *Atylotus duplex* and also by Jezek (1977).

Specimens examined. 28 ♀♀, 32 ♂♂, from localities plotted on Fig. (7) and 2 ♀♀, 5 ♂♂ from Abisko, Sweden and Murnauer, Germany. Specimens deposited in C.N.C., Cornell Univ., Univ. Minnesota, Ohio State Univ., Calif. Acad. Sci.

Remarks. The European adults of *Atylotus sublunaticornis* that were examined, and descriptions of this species given by Olsufjev (1977) and Chvala, Lyneborg and Moucha (1972), are clearly the same as the above Nearctic specimens. Larvae of the Palaearctic form, described by Jezek (1977), differed from Nearctic specimens in the absence of pubescence on the anterior margins of the meso- and metathorax.

This species and *ohioensis* are the only known solely white- and black-haired forms. All others, except for the occasional specimen of *sphagnicolus*, have some of the pale hairs on the scutum and abdomen at least faintly yellowish and, except for *bicolor*, contrasting with the pure white hairs on the thoracic pleuron. Whereas, in *sublunaticornis* there are abundant black hairs, including the postocular fringe, *ohioensis* is dominantly white-haired.

One specimen of *sublunaticornis* from Doyle, Nfld. has slightly yellow abdominal tergal hairs. That it is merely a variant seems assured, based on similarities in the pattern of pale and black tergal hairs and the white calypteral tuft of hairs. Males collected at the same time have the normal abdominal hair pattern and color and a completely black postocular fringe. In species having normally yellowish abdominal hairs, the postocular fringe is almost invariably partially yellow-haired.

The close similarity of larvae of *sublunaticornis* to those of *palus*, and means of differentiating the two are discussed under the latter species.

The only locality where larvae of this species have been collected is the one at Puslinch, Ontario that has also yielded *Atylotus palus* and *A. hyalicosta* described here, and *A. woodi* described by Pechuman (1981). The habitat was briefly described by Teskey (1969) and seems to correspond closely to what is classified as a fen by Tarnocai (1980).

Atylotus ohioensis (Hine)

Tabanus pruinosus Hine, 1900:248 (preocc. Bigot, 1892).

Tabanus ohioensis Hine, 1901:28 (new name for *pruinus* Hine).

Female. Length 8-10 mm. Head dark greyish on occiput and genae, more or less yellow on frons, subcallus, frontoclypeus, and upper portion of genae; all covered with whitish pruinosity and white hair, including postocular fringe. Eye usually with partial transverse stripe in dried specimens and relatively long dense pile. Frons 2.3-3.0 times as long as basal width, essentially parallel-sided. Basal flagellomere subquadrate, 1.0-1.3 times as long as greatest width, with dorsal angle obtuse and no dorsal excision; terminal flagellomeres shorter than width of basal flagellomere. Second palpomere swollen basally, 1.9-2.5 times as long as greatest diameter, tapered uniformly to sharp point, mostly white-haired with black hairs mainly on apical half.

Thorax dark, covered with whitish pruinosity and predominantly white hairs, with a few black hairs on notopleura and usually sparsely distributed over scutum. Legs predominantly yellow with coxae and base of femora greyish black. Wing with all membranous areas hyaline. Halter yellow.

Abdomen blackish with pale hairs on tergites and sternites white, such hairs almost exclusively on sternites while on tergites exclusively on more or less of lateral and caudal margins and usually intermixed with dominant black hairs on discal areas of tergites.

Male. Apart from usual sexual differences, differs from females as follows: eye with dense long, white pubescence; postocular fringe of long white hair; scape and pedicle of antenna usually completely white-haired or with very sparse black hairs, and basal flagellomere more slender and usually with shallow dorsal excision; thoracic scutal hairs completely white; abdomen with sides of tergites 1 to 3 yellow and all tergites predominantly white-haired including median discal areas.

Mature larva and pupa. Described by Teskey (1969).

Specimens examined. 38 ♀♀, 39 ♂♂, including syntypes in the U.S.N.M. and Ohio State Univ., distributed as plotted in Fig. (8). One of these syntypes in Ohio State University, a female bearing a handwritten label "Medina, 0.6-27-99", has been selected as lectotype and so labelled on the specimen.

Comments. Adults of this species are distinctive by virtue of their smaller size, by all pale hairs, including the postocular fringe and setae on the anterior wing veins of both sexes, being white and by the subquadrate basal flagellomere. Specimens of *Atylotus sublunaticornis* are the only others where the pale hairs are extensively white, but they differ in having the postocular fringe and wing vein setae black, and a more slender basal flagellomere. Members of *Atylotus thoracicus* are actually the most similar, but are readily distinguished by the pale hairs on the scutum and by the abdomen showing at least a slight yellowish tinge which is especially evident in contrast to the white hairs on the thoracic pleuron. Additionally, there are fewer black hairs on the abdominal tergites, notopleural lobes and palpi of *thoracicus*, especially in females, and the integument on the sides of the abdominal tergites is more extensively yellowish.

Atylotus sphagnicolus n.sp.

Atylotus pemeticus of most authors, not Johnson.

Female. Length of body 8-11 mm, of wing 7-9.5 mm, brownish-black in general appearance. Eyes lacking transverse stripe, very sparsely short pilose. Frons 2.8-3.5 times as long as basal width, nearly parallel-sided, with underlying integument usually black medially, bordered

by yellow, and covered with greyish-brown pruinosity and yellow and black hairs. Vertex and median occipital sclerite usually similarly colored. Postocular fringe of predominantly black hair. Subcallus with yellow integument and covering pruinosity. Antenna yellowish; scape and pedicel a paler tone, with yellow and black hairs; basal flagellomere $\frac{1}{3}$ to $\frac{1}{2}$ longer than greatest width, with weak dorsal angle and no dorsal excision, about 1.5 times as long as terminal flagellomeres. Second palpomere creamy-white, 2.3-3.7 times as long as greatest diameter, with long, mainly black hair.

Thorax with pleura and coxae white pruinose, white-haired; scutum brownish pruinose with recumbent yellow hair and sparser erect black hair. Leg segments beyond coxae mainly yellow, although base of femora usually darkened. Halter yellowish-orange. Wing with costal, humeral and stem cells yellow-tinted and contrasting with clear membrane elsewhere; anterior wing veins with predominantly black setae; calypteral tuft of hairs usually yellow.

Abdominal integument predominantly brownish-black with sides of first two tergites narrowly yellow; all tergites exclusively very pale to bright yellow-haired laterally and on posterior margins but usually mixed with black hairs elsewhere, but in some specimens with black hair forming dominant or exclusive patches anteriorly or sublaterally near anterior margins of first three or four tergites. Sternum blackish with pale yellow to white hair, with sparse black hair on terminal three visible sternites.

Male. Apart from normal sexual differences, differs from female as follows: postocular fringe with long, predominantly black hairs; eye hairs white, very dense and about 1.5 mm long. Femora usually with basal half, or more, blackened. Yellow and black hairs uniformly mixed on abdominal tergites 1 and 2 but on tergites 3 to 5 black hair predominant in anterior and sublateral positions.

Mature larva (Fig. 4). Creamy-white, approximately 18 mm long. Head capsule 2.8 mm long. Tracheal trunks slender. Anal segment subspherical, about as long as greatest diameter. Respiratory siphon length about equal to basal diameter. Pubescence present on all segments. Anterior pubescence encircles first eight segments and progressively more widely absent laterally on next two segments and dorsally on tenth segment; thoracic annuli with caudal projections, two clavate projections laterally on each side of prothorax and a midventral pointed projection and four pointed projections on each side of meso- and metathorax, those on mesothorax $\frac{1}{2}$ - $\frac{2}{3}$ length of segment, those on metathorax very short; annuli on anterior abdominal segments wide laterally, abutting or only narrowly separated from lateral pseudopodia. Pseudopodial pubescence encircles first seven abdominal segments. Posterior pubescence encircles terminal five segments and progressively reduced laterally and ventrally on preceding two segments. Anal segment with median pubescent extension from anal ridges to a dorsolateral position, with two short caudal projections laterally and dorsolaterally.

Pupa. Length 15 mm. Integument predominantly light brown with darker median and sublateral areas dorsally on thorax and on vertex of head; a short darker stripe between antennal ridges and three faintly darker longitudinal stripes on frontal plate behind antennal ridges; abdominal tergites brighter and darker than opaque intersegmental areas. Antennal and frontal ridges similar, low rugose areas; former separated by rather wide median cleft. Callus tubercles conical, elevated about 0.06 mm. Thoracic spiracles 0.45 mm long, evenly bowed, mounted on shallow prominences not extending anteriorly beyond thoracic margin. Abdominal spiracles progressively shorter from 0.2 mm for spiracle 1 to 0.09 mm for spiracle 7. Fringes of spines complete on all but lateral third of abdominal sternite 2, spines essentially uniseriate on tergites 1 and 2 and sternites 1 and 6, indistinctly biseriate elsewhere; individual spines slender and acute, progressively larger on posterior segments; tergite 7 with 70 spines, longest about 0.4 mm. Ventral and especially lateral preanal combs with short spines; dorsolateral combs absent. Dorsal, lateral, and ventral tubercles of aster approximately 0.18, 0.4 and 0.18 mm long, respectively, former two pairs inclined dorsally at about same angle and both with apices somewhat hooked ventrally.

Type specimens. Holotype ♀, Kouchibouguac National Park, New Brunswick, 20.VII.77, G.A. Calderwood (Code - 5664V), Canadian National Collection No. 18148; allotype ♂, with same data except 28.VI.77 (Code 5444J); paratypes; 132 ♀♀, 107 ♂♂ from localities plotted on Fig. (9). Included in the paratype series is one specimen reared from a larva collected in a sphagnum bog near Alfred, Ontario. Two other, identically reared specimens from the same locality died in the pupal stage. Paratypes are deposited in: C.N.C., U.S.N.M., Cornell Univ., M.C.Z., Cal. Acad. Sci., Nova Scotia Prov. Mus., Univ. Montreal, Ill. Nat. Hist. Surv., Univ. New Hampshire, F.S.C.A. and collection of Dr. A.W. Thomas.

Comments. The pale scutal and abdominal hairs among adults of this species vary quite widely in color tone from distinctly yellow to nearly white in all or in part. The latter extreme has been observed particularly in specimens from the northern part of the species range between 45-48° N lat. A conspicuous feature of most of these specimens is a white calyptal tuft of hairs. These features were initially considered of specific significance but the presence of some distinctly yellow-white specimens throughout this zone, including some collected in the same series as the whitish-haired specimens, indicates their conspecificity. This is further confirmed by the probable breeding site of all specimens, representing the entire color spectrum, being acidic sphagnum bogs. The one larva of this species that was reared, yielding a female with white calyptal tuft, was collected in such a bog at Alfred, Ontario. All but one of the adult collection localities of which I have personal knowledge, or have confirmed with the collectors of the specimens, which involves about 60 percent of the localities, were sphagnum bogs.

Another group of variant specimens, tentatively identified as this species, but not included as paratypes, are a species of 19 females collected in a sphagnum bog on the TransCanada Hwy., Victoria Co., Nova Scotia, and 8 other females from Nova Scotia, New Brunswick, Maine and Michigan. These specimens are all at the maximum body size for *sphagnicolus*, with more swollen palps and broader basal flagellomere. Statistical analysis of the dimensions of these structures compared with a similar series of typical specimens of *sphagnicolus* in the same or nearby bogs to the one on the TransCanada Hwy. showed a significant difference at the 95% level. The specimens also differ in having the setae on the anterior wing veins predominantly yellow. Apart from this latter feature these specimens resemble *Atylotus intermedius* as reinterpreted here. However, in addition to the vein setal color difference, there is no indication in any of the specimens of denuded areas on the frons or of small elevations on the frons where natural abrasion might create the glossy calli that are distinctive of most females of *intermedius*. Further collections, including the larvae of this form, and association with males will likely be necessary before the true significance of these variations can be known.

Adults of *Atylotus sphagnicolus* are quite similar to *A. palus* in size, dimensions of frons, palps and flagellum and also in the pattern and coloring of hairs on the body. It is frequently difficult to distinguish the females of the two species. The only difference is the brighter yellow hairs and more prominent isolation of groups of black and yellow hairs on the abdominal tergites of *palus*. Males may be readily distinguished by the color of hairs on the upper margin of the mesanepisternum, yellow in *palus*, white in *sphagnicolus*, and the difference in length of the eye hairs. The nature of the collection site, whether a sphagnum bog or a fen, should also contribute to an accurate identification.

The larva of *sphagnicolus* resembles those of *ohioensis* and *thoracicus*, as described and illustrated by Teskey (1969), but more closely the former, based on similarly clavate pubescent projection on the prothorax and greater similarities of abdominal pubescence. All 3 species are quite different from that of *duplex* which was also described in the same publication, but under the name of *pematicus*. It differs from both in a somewhat intermediate development of anterior pubescence and in the more extensive development of posterior pubescence. The pupa differs from those of *ohioensis* and *thoracicus* in having darker and

more extensive integumental markings, these forms having either no contrasting darker areas of the integument or only a median dark spot on the thorax and no darkening of the head, and almost no contrast between abdominal sclerites and intersegmental integument. Also, the antennal ridges of *ohioensis* are distinctly larger and more ridge-like, not simply a wrinkling of the integument.

Atylotus thoracicus (Hine)

Tabanus thoracicus Hine, 1900:248.

Female. Length 8-11 mm. Head with subcallus and more or less of frons and median occipital sclerite yellow, remainder black, covered with mainly white pruinosity and white to faintly yellow hairs, including postocular fringe. Eye rarely with partial transverse dark stripe in dried specimens. Frons 3.3-4.2 times as long as basal width, nearly parallel-sided. Basal flagellomere of antenna 1.2-1.7 times as long as greatest width with obtuse dorsal angle and little or no dorsal excision; terminal flagellomeres about as long as width of basal flagellomere. Second palpomere 2.4-3.3 times as long as greatest diameter, constricted and pointed apically; sparsely black-haired.

Thorax and coxae black, covered with whitish pruinosity, with white hairs on pleuron and coxae, and yellowish hairs on scutum and scutellum, usually sparse black hairs only on notopleural lobes. Legs, except coxae, predominantly yellow; base of mid and hind femora sometimes blackened, predominantly black-haired. Wing with costal cell faintly yellow-tinted; setae on anterior veins usually predominantly yellow. Halter yellow. Calypterale tuft of hairs faintly yellow.

Abdomen usually with side of first three or four tergites broadly yellow, leaving dark greyish median stripe, that expands posteriorly; sternites predominantly yellow, usually with sternite 1 and median triangle on sternite 2 dark; entire abdomen with yellow hair except for sparse erect black hairs on terminal two or three tergites and sternites.

Male. Apart from usual sexual difference, differs from female as follows: postocular fringe of hairs long, usually extensively black; thorax with longer hair, including some black hair among yellow hairs on scutum; basal $\frac{1}{3}$ or more of femora blackened; abdomen with rarely more than lateral third of anterior tergites yellow, sternites usually mostly black and all tergites and sternites usually with black hairs mixed with yellow hairs medially.

Mature larva and pupa. Described by Teskey (1969).

Specimens examined. 129 ♀♀, 127 ♂♂, including lectotype ♀ in U.S.N.M., distributed as shown in Fig. 10.

Comments. Adults of this species are readily distinguished by the character combination of scutal and abdominal pale yellowish hairs; sparse black hairs on palps, notopleural lobes, scutum and abdomen; postocular fringe of hairs white in female and at least partly black in males; setae on anterior wing veins mostly yellow.

Adults have apparently never been collected outside the confines of acidic sphagnum bogs. Here they seem to be restricted to the open bog moor, away from the lowest of shrub growth. They seem to be rather sedentary, flying only when disturbed and then for only short distances. There are no records of their attempting to take blood. Larvae have been found in compacted sphagnum moss interlaced by grass roots in drier portions of a bog mat, devoid of shrubby growth (Teskey 1969).

Atylotus woodi Pechuman

This species was recently described by Pechuman (1981). I can add nothing to his descriptions or comments. The larva and pupa of this species were described by Teskey (1969)

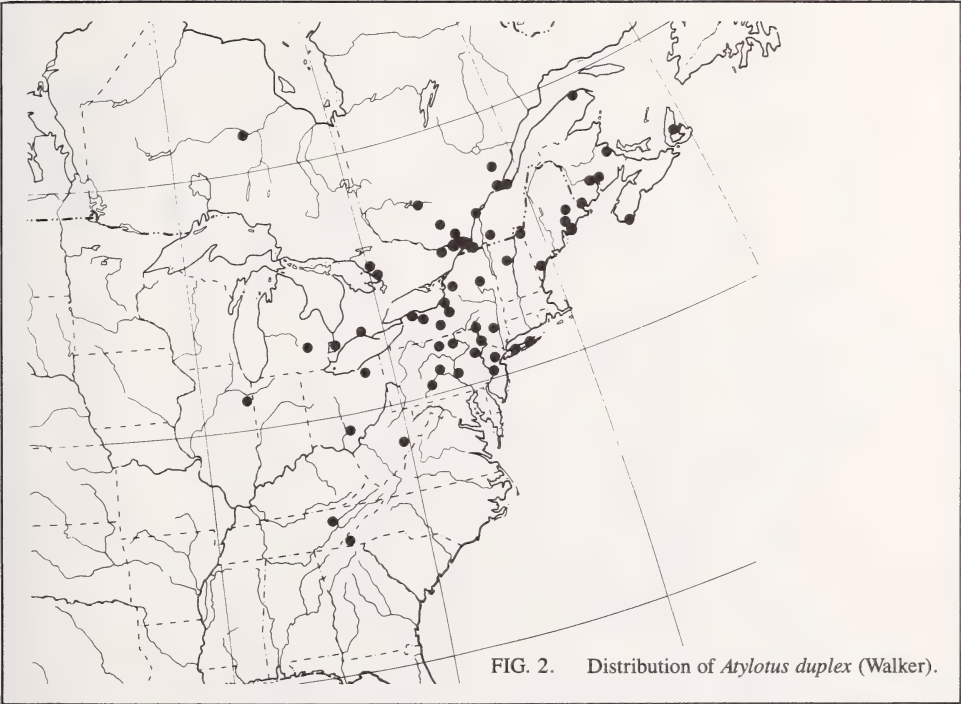
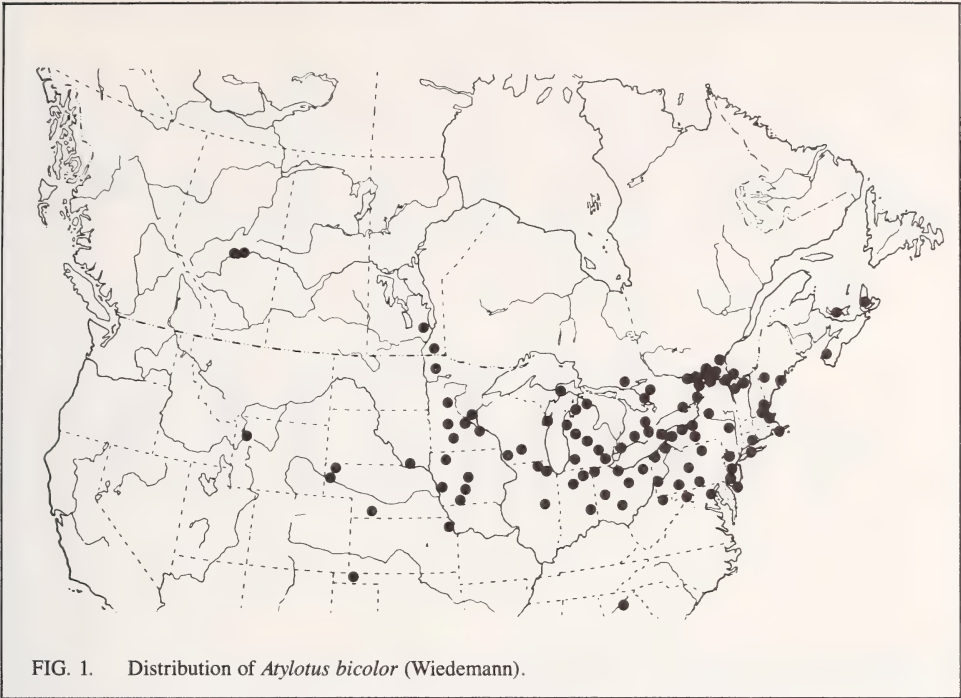
under the designation "sp.C". The habitat in which they were found, a marl bog near Puslinch, Ontario, has produced immatures of several other *Atylotus* discussed here.

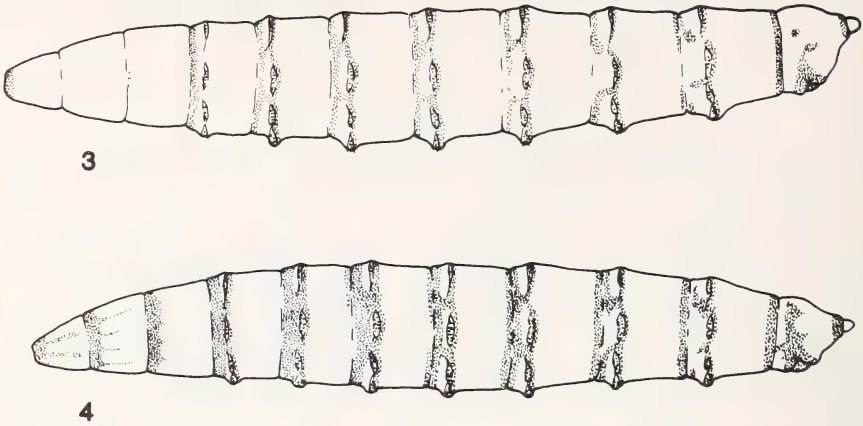
Only one other locality can be added to the distributional picture given by Pechuman, and this is a grassy fen near Richmond, Ontario, where 2 females were collected on 11 August in both 1978 and 1983.

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FIGS. 3,4. Larva of *Atylotus palus* n.sp. (3) and *Atylotus sphagnicolus* n.sp. (4).



FIG. 5. Distribution of *Atylotus palus* n.sp.

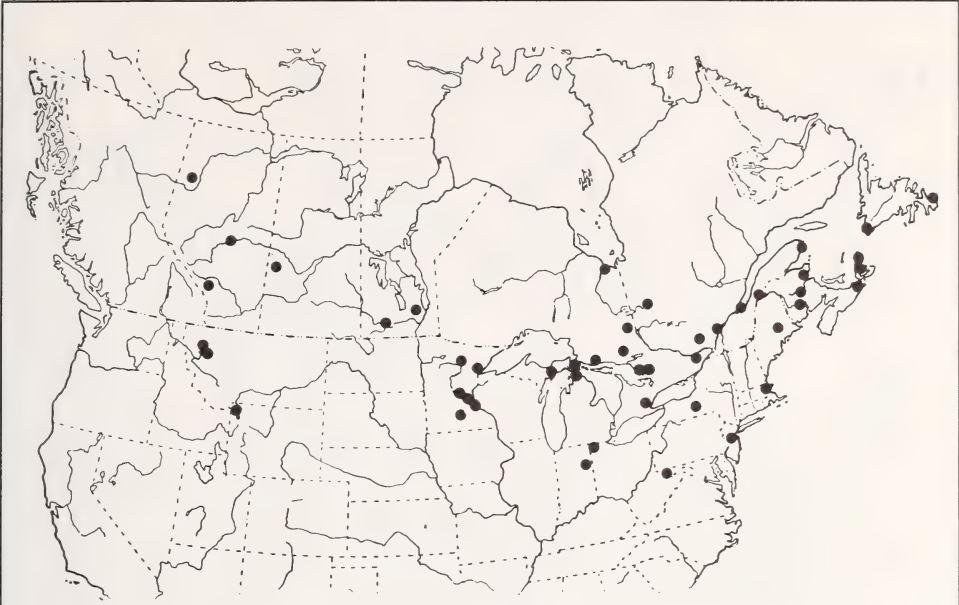


FIG. 6. Distribution of *Atylotus hyallicosta* n.sp.



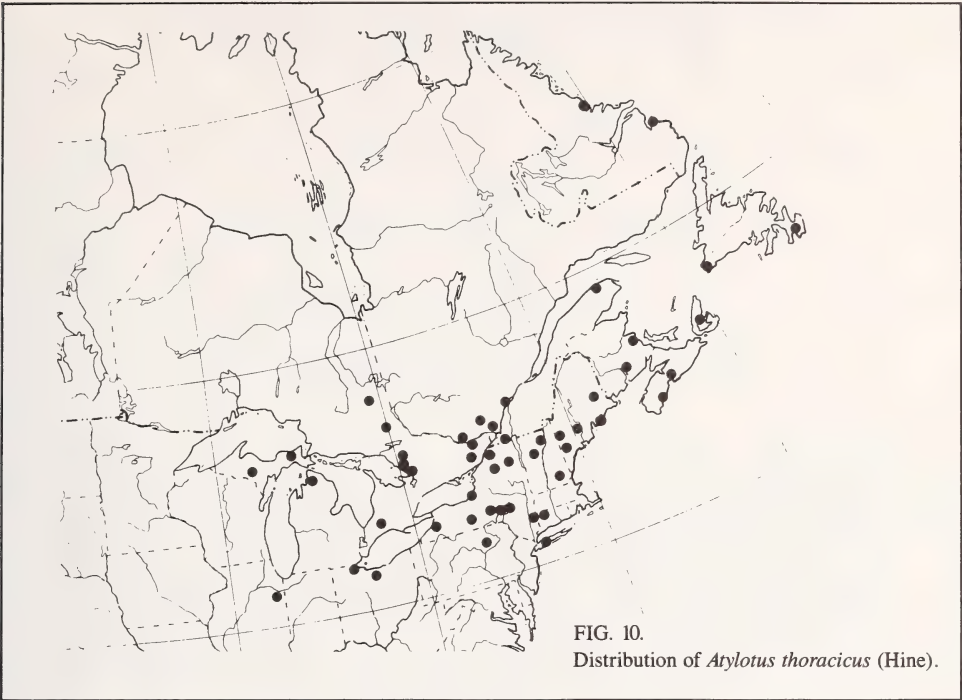
FIG. 7. Distribution of *Atylotus sublunaticornis* (Zett.).



FIG. 8 Distribution of *Atylotus ohioensis* (Hine).



FIG. 9. Distribution of *Atylotus sphagnicolus* n.sp.



POLLINATION OF CRANBERRIES, *VACCINIUM MACROCARPON*, ON CULTIVATED MARSHES IN ONTARIO

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Abstract

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The large cranberry, *Vaccinium macrocarpon* Aiton (Ericaceae) is dependent on insects for pollination and fruit-set. The presence of honeybees on two commercial cranberry marshes near Bala, Ontario, had no detectable effect on pollination or fruit production of either variety, Searls Jumbo and Stevens, studied. Fruit size, seed counts, and fruits produced per flower were compared at various distances from honeybee hives and between sites (cultivars). Differences between sites were significant and suggest the combined effects of differences in cranberry cultivars and in native pollinator populations. A wide variety of insects (native pollinators) were censused and collected from cranberry flowers. *Bombus terricola* and *B. vagans* were important pollinators. The role of the large numbers of *Toxomerus* spp. (Syrphidae) on the flowers was not assessed, but may be important.

Introduction

Vaccinium macrocarpon Aiton (Ericaceae), the large cranberry, has been cultivated in Ontario since 1953 when Orville Johnston started growing them near Bala. In 1969 the Mohawk Indians of the Gibson Band started growing cranberries in the same area. Although these pioneering efforts have been successful (Anonymous 1984; Smith 1980), there has been concern as to the adequacy of pollination of the flowers to bring about maximum crops.

V. macrocarpon is dependent on insects for pollination (McGregor 1976; Free 1970). Bumblebees are excellent cranberry pollinators and should be encouraged in the vicinity of producing commercial marshes (Johansen and Hutt 1963). The importance of other insects which visit cranberry flowers is not known. In general, it is recommended that one strong colony of honeybees per acre be used to ensure pollination (Stewart 1970; Stewart and Marucci 1970; McGregor 1976) even though it is known that cranberry flowers offer little reward in either nectar (Marucci 1967; Shaw *et al.* 1956) or pollen (Shimanuki *et al.* 1967; Marucci 1967), for them. The value of honeybees to cranberry pollination is debatable. Various experiments in which bees were excluded from cranberry flowers showed less berry crops in bee-free cages. However, at least some of these experiments also excluded native insect pollinators. The claim by Swenson (1958) that no honeybees result in no cranberries is erroneous and extreme. The view expressed by Hutson (1925, 1927) that honeybees should be used as insurance against those years when native pollinators are less abundant is more balanced (see also MacKenzie and Winston 1984). Even so, the value of honeybees needs more critical assessment as cranberry flowers are not highly attractive to honeybees, and the bees do not forage on the flowers distant from hives (Filmer 1949). Small- to moderate-sized marshes may not require supplemental pollination, but those over 50 acres may (Filmer and Doehlert 1959). Moeller (1979) has shown that if honeybees are left for 4 days on cranberry marshes maximum pollination is achieved.

Our objective was to examine the general level of pollination on cranberry marshes in Ontario, and to determine the value of honeybees placed on marshes by growers. At the same time we made an inventory of native pollinators of cranberry occurring on the marshes with a view to assessing their importance.

Materials and Methods

The work described herein was conducted near Bala, Ontario on the cranberry marshes operated by Cranberry Products of Canada Limited (CPC) and the Iroquois Cranberry Growers (ICG) (Fig. 1). The varieties of cranberries studied were Searls Jumbo at the CPC marsh and Stevens at the ICG marsh. At both sites 12 hives of honeybees were used. We are unaware of any others in the vicinity of the marshes. At each site one-meter² plots were marked with stakes and string for pollinator watches, floral counts, and berry production (Fig. 1). Two observers spent 10 min at each plot counting and categorizing cranberry flower visitors. This was done so that each plot was examined during each observation period at least once with the observers alternating. At the same time the numbers of honeybees in the plots and vicinity (25 m²) were recorded. Honeybees were also estimated on the marshes by 2 observers, working together for 2 minutes (4 man minutes), counting honeybees flying within an approximate 4-m-radius semi-circle (total ca. 50 m²) (Fig. 1). Table I represents the man hours of observation for each type of sample, the dates, and the approximate times of sampling. The weather was warm, generally sunny, and calm when pollinators were sampled.

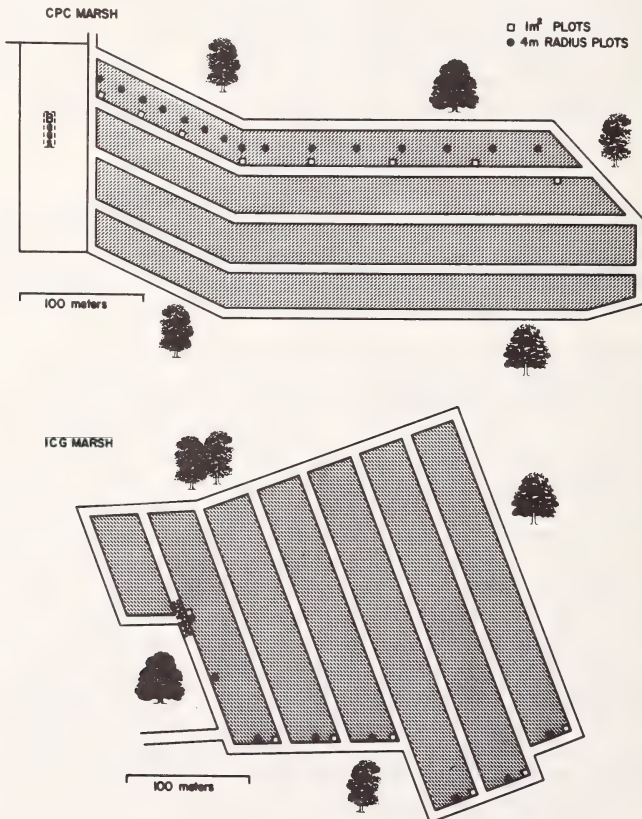


FIG. 1. Sampling locations for pollinators of cranberries: CPC, Cranberry Products of Ontario marsh; ICG, Iroquois Cranberry Growers marsh.

Table I. Observation schedule for pollinators on commercially grown cranberries at two sites near Bala, Ontario

Date (1983)	Time (EDST)	Site	Man Hours	No. of Stations
10-minute watches at 1-m ² plots				
7 July	12:30 - 17:45	¹ CPC	4.00	8
13 July	17:00 - 18:00	CPC	1.33	8
14 July	11:00 - 13:15	² ICG	2.33	7
2-minute watches over 50 m ²				
7 July	18:00 - 18:45	CPC	0.50	15
13 July	18:15 - 19:00	CPC	0.50	15
14 July	13:30 - 15:00	ICG	0.52	8

¹Cranberry Products of Canada Limited marsh²Iroquois Cranberry Growers marsh

At each site, within the 1-m² plots, 20 flowering uprights of cranberry were marked with string circles or chicken leg-bands. The flowers were counted for each upright and later the resulting fruits were counted and harvested. The diameter of each fruit was measured and its volume then calculated. Each fruit was cut open and the seeds counted. The relationship between fruit size and seed number was determined by simple linear regression analysis. The importance of honeybee pollination on cranberries was determined by examining the fruit- and seed-set/flower in relation to the distance of the plot from the honeybee hives (simple linear regression analysis). The numbers of honeybees seen on cranberry flowers during watches was then related to the distance of the hive. Comparisons between the sites for flowers per upright, fruits per upright, fruits per flower, seeds per flower, and size of fruit were made using the Student's t-test.

Statistical procedures are described by Zar (1974). The maximum probability of a Type-I error was set at 0.05 for all procedures.

Results

About 25 species of insects were collected as they visited cranberry flowers (Table II).

The counts of insects known to visit cranberry flowers are highly variable as seen on the 1-m² plots, as can be seen in Table III which presents the average numbers of *Toxomerus* spp. (Syrphidae), other Syrphidae, *Bombus* spp. (Apidae), and other Hymenoptera (excluding *Apis mellifera*) for each site, along with the high standard deviations for those numbers. The numbers of pollinators on each site are not significantly different between sites. Within pollinator types differences emerge between sites. Bumblebees are almost twice as abundant at CPC ($t = 5.43$; $P < .001$) as are Syrphidae other than *Toxomerus* spp., but only marginally significantly so ($t = 2.64$; $P \approx .01$). Honeybees are treated separately, and the numbers, calculated as those seen per man hour per 10 m², are presented in Table IV together with the distance of the observation points from the hives. The numbers of foraging honeybees on cranberries were low regardless of distance from the hives. Furthermore, few honeybees foraged on cranberries beyond 200 m from the hives and they mostly stayed within 100 m of them.

The regression lines of best fit of the linear relationships between mean number of fruits at various distances from the hives were not significantly different from zero ($F = 3.69$, $P = 0.06$ for CPC; $F = 0.24$, $P = 0.62$ for ICG) (Fig. 2). Our results for seed per flower at various distances from the hives show similar effects (Fig. 3); the regression lines are not significantly different from zero ($F = 1.43$, $P = 0.23$ for CPC; $F = 3.43$, $P = 0.07$ for ICG).

Table II. Flower visitors to commercially grown cranberries in Bala, Ont.

Order	Family	Species	Abundance (Numbers collected)	
			CPC ¹	ICG ²
Diptera				
	Syrphidae			
		<i>Eristalis dimidiata</i> Wd.	4	2
		<i>Metasyrphus</i> sp.	1	1
		<i>Sphaerophoria asymmetrica</i> Knut.	1	0
		<i>S. philanthus</i> (Mg.)	0	1
		<i>S.</i> sp.	1	0
		<i>Toxomerus geminatus</i> (Say) ³	6	2
		<i>T. marginatus</i> (Say) ³	4	3
	Tabanidae			
		<i>Hybomitra pechumani</i> Teskey and Thomas	1	2
	Other Diptera		5	3
Hymenoptera				
	Apidae			
		<i>Apis mellifera</i> L. ³	4	3
		<i>Bombus terricola terricola</i> Kirby ³	12	9
		<i>B. vagans vagans</i> Smith ³	3	1
		<i>B. ternarius</i> Say	2	0
		<i>Psithyrus ashtoni</i> (Cresson)	3	1
	Eumenidae			
		<i>Aneistrocerus</i> sp.	0	1
	Halictidae			
		<i>Augochlorella striata</i> (Provancher)	0	1
		<i>Dialictus</i> sp.	1	0
		<i>Halictus rubicundus</i> (Christ)	1	0
	Philanthidae			
		<i>Philanthus bilunatus</i> Cr.	0	1
	Pompilidae			
		<i>Episyron biyuttatus</i> (Fab.)	0	1
	Vespidae			
		<i>Dolichovespula arenaria</i> (F.)	0	1
		<i>Vespula consobrina</i> (Sauss.)	0	2
		<i>V. maculifrons</i> (Buys.)	1	0
		<i>V. vidua</i> (Sauss.)	2	1
Lepidoptera				
		<i>Clossiana selene atrocostalis</i> (Huard)	2	0

¹Cranberry Products of Canada Limited marsh

²Iroquois Cranberry Growers marsh

³*A. mellifera*, *Bombus*, and *Toxomerus* were not collected as often as they occurred. As a result their abundance is underestimated relative to the other flower-visiting species.

The effects of pollination for any given cultivar can be seen in the number of fruits/flower and the number of seeds/flower (Table V). The fruit set at the CPC marsh was on average 56% greater than at the ICG marsh, a difference which is highly significant (Student's $t = 5.92$, $P < 0.001$). The number of seeds per flower was on average 160% greater at the CPC marsh than at the ICG marsh (Student's $t = 8.61$, $P < 0.001$). Within cultivars we document an increase in fruit size with an increase in seed number. These relationships are significant (diameter vs. seed number $F = 232.07$, $P < 0.0001$, $r^2 = 0.48$, CPC; $F = 131.95$, $P < 0.0001$, $r^2 = 0.46$, ICG; volume vs. seed numbers $F = 249.38$, $P < 0.001$, $r^2 = 0.49$, CPC; $F = 255.54$, $P < 0.0001$, $r^2 = 0.59$, ICG). We have used seed number as the independent variable and fruit size as the dependent because we presume that the greater the success of pollination, the more ovules will be fertilized, the more seeds will develop, and so the fruit should be larger (Hall and Aalders 1965).

Table III. Numbers of insects observed calculated as those seen per man/h/ 10 m², in commercial cranberry fields in Bala, Ontario

	CPC ¹			ICG ²		
	Mean	S.D.	N	Mean	S.D.	N
<i>Toxomerus</i> spp.	600	460	32	596	372	14
Other Syrphidae	30	46	32	17	37	14
<i>Bombus</i> spp.	15	26	32	9	22	14
Other Hymenoptera (excluding <i>Apis mellifera</i>)	34	50	32	34	45	14

¹Cranberry Products of Canada Limited marsh

²Iroquois Cranberry Growers marsh

Table IV. Honeybees seen visiting flowers of commercially grown cranberries near Bala, Ontario at various distances from the hives placed on the marshes

Site	Distance from hives (m)	Weighted mean number of honeybees calculated per man/h/ 10 m ²	Range	N	Minutes of observation
CPC ¹	0-100	5.74	0-15.0	14	94
	101-200	1.32	0- 6.0	16	100
	201-400	0.00	0	24	168
ICG ²	0-100	3.69	0- 6.0	5	26
	101-200	1.56	0- 3.6	9	54
	201-325	0.00	0	9	54

¹Cranberry Products of Canada Limited marsh

²Iroquois Cranberry Growers marsh

Table V. Varietal differences between commercially grown cranberries near Bala, Ontario

	Searls Jumbo			Stevens			Student's t	P > t
	X	S.D.	N	X	S.D.	N		
Fruits per flower	0.53 ± 0.27		160	0.34 ± 0.26		140	5.92	<0.001
Seeds per flower	5.2 ± 3.8		160	2.0 ± 2.4		140	8.61	<0.001
Flowers per upright	3.2 ± 0.8		160	3.8 ± 1.4		140	4.06	<0.001
Fruits per upright	1.7 ± 0.9		160	1.3 ± 1.0		140	3.80	<0.001
Fruit diameter (cm)	1.4 ± 0.32		258	1.33 ± 0.34		159	2.12	0.034
Fruit volume (cc)	1.63 ± 0.81		258	1.44 ± 0.71		159	2.54	0.011

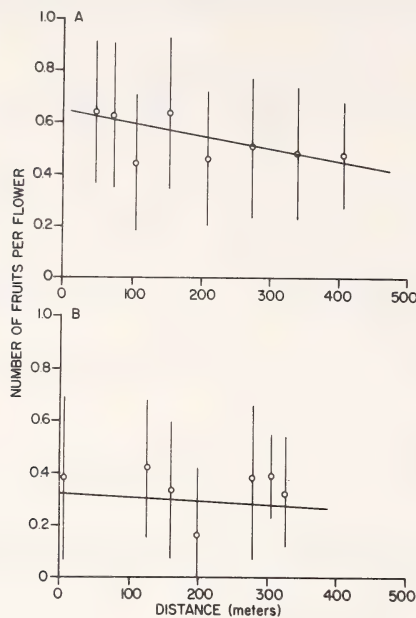


FIG. 2. Linear relationship between foraging distance of honeybees and the mean number of fruit. Verticle bars extend one S.D. on either side of the mean and the equation describes the line of best fit: A, CPC marsh, $Y = (\text{sine } (53.2694 - 0.0273X))^2$; B, ICG marsh, $Y = (\text{sine } (34.4050 - 0.0087X))^2$.

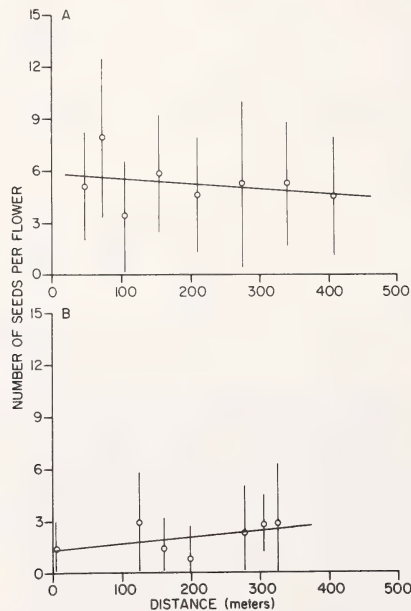


FIG. 3. Linear relationship between foraging distance and mean number of seeds per flower. Verticle bars extend one S.D. on either side of the mean and the equation describes the line of best fit: A, CPC marsh, $Y = 5.7946 - 0.0030X$; B, ICG marsh, $Y = 1.3246 + 0.0036X$.

Discussion and Conclusions

We conclude from our results that honeybees did not contribute significantly to pollination of the cranberries we studied. There is no relationship between the parameters chosen to indicate pollination success, i.e. fruits per flower and seed per flower, and the distance of the plants from honeybee hives. In as much as one would expect honeybee densities on cranberry flowers to be higher close to the hives, which indeed we found, one would expect better pollination. However, we found that, even close to the hives, honeybees were scarce and apparently in insufficient numbers to influence fruit production. Honeybees do not find cranberry flowers rewarding as they produce only small amounts of nectar and pollen. In fact, we found that the honeybees were visiting more rewarding plants than cranberry, e.g. fireweed, basswood, and various roadside weeds at considerably greater distances from the hive than the furthest corners of the cranberry marshes.

Although honeybees have been indicated as being beneficial to cranberry pollination in Massachusetts (Tomlinson 1969; Demoranville 1981), Wisconsin (Farrar and Bain 1947; Rigby *et al.* 1972), New Jersey (Filmer and Doehlert 1959; Marucci 1967; Stewart and Marucci 1970; Marucci and Moulter 1977) earlier workers in New Jersey (Hutson 1925, 1927), Massachusetts (Franklin 1940), and Wisconsin (Rigby *et al.* 1972) indicated that wild bees, particularly bumblebees, were sufficiently abundant to bring about thorough pollination. Records of increased yields with increased number of bees on cranberry lands (eg. Filmer 1953) suggest that honeybees should be used, yet experiments which conclusively demonstrate their superiority over native bees for pollination are wanting. On large areas of cranberry marshes honeybees may be beneficial because of the lower density of native pollinators and the lack of nearby alternate forage for honeybees. Year to year differences in populations of native pollinators, differences in the length and warmth of the blooming season (eg. Wood 1961 for lowbush blueberry), and the effects of pesticides (NRCC 1981) all indicate that honeybees should be considered as possible insurance for pollination on cranberries in Ontario. However, clearly more information is needed on how they might be managed (see Moeller 1973) and on the methods to be used to encourage native bee populations.

The large number of Syrphidae, especially *Toxomerus* spp. may be important in pollination. The bumblebees, *Bombus terricola terricola* in particular, were quite abundant and diligent in their foraging on cranberry. Very few solitary bees were encountered. The diversity of flower visitors to cranberry is low (see also Roberts 1979; MacKenzie and Winston 1984).

The significantly greater density of *Bombus* at CPC correlates with the better pollination success there. The 1.56 times greater fruit set per flower, the 2.60 times greater seed set per flower (Table V) and the 1.67 times greater number of *Bombus* at CPC than at ICG is highly suggestive of the importance of these insects. It is also worth noting that Stevens cultivar generally produces larger berries than does Searls Jumbo, yet we found them to be smaller than the latter (Table V), again reflecting poor seed set and perhaps less than adequate pollination (see Hutson 1926; Farrar and Bain 1947; Hall and Aalders 1965; Rigby and Dana 1971).

We recommend that attempts be made to encourage native pollination of cranberry around the marshes. *Bombus* spp., especially *B. terricola terricola* and *B. vagans vagans*, seem particularly valuable. More research is needed to determine how Syrphidae might be encouraged. *Toxomerus* larvae are aphidophagous, as far as is known (Vockeroth 1969), but the prey for the larvae of the *Toxomerus* spp. which we found as adults on cranberry flowers is not known. The value of the adults of these hoverflies, and others, in pollination needs further examination.

Acknowledgements

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BEHAVIOURAL INTERACTIONS BETWEEN A SOCIAL PARASITE, *PSITHYRUS CITRINUS* (HYMENOPTERA: APIDAE), AND ITS BUMBLE BEE HOSTS

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Abstract

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Dominance behaviour of the bumble bee social parasite *Psithyrus citrinus* (Hymenoptera: Apidae) is examined. *Psithyrus* females mauled host bees after being introduced into laboratory colonies of *Bombus vagans* and *B. impatiens*, resulting in temporary, or permanent displacement of host queens and workers from the comb. Mauling behaviour decreased in frequency following the first few days of comb occupation. Bees which returned to the comb after being mauled assisted *Psithyrus* females in rearing offspring. *Psithyrus* females were unable to suppress ovarian development of workers if they were separated from *B. impatiens* workers by wire mesh screen. Physical dominance is proposed as the mechanism parasites use to prevent egg-laying and oophagy by host bees.

Introduction

Species of *Psithyrus* (Hymenoptera: Apidae) are obligate social parasites of bumble bees (*Bombus* spp.). Little is known about their biology (e.g. Free and Butler 1959; Alford 1975). Some species of *Psithyrus* are thought to cohabit with host queens (Hoffer 1889; Webb 1961), whereas others are believed to kill or displace host queens upon successfully invading bumble bee colonies (Sladen 1912; van Honk *et al.* 1981).

Elsewhere, I have argued that *P. citrinus* Smith, a *Psithyrus* species thought to kill or displace host queens (Plath 1934) should be capable of suppressing ovarian development in host workers, i.e. dominating them (Fisher 1984a). Enlargement of ovaries occurs in queenless workers, and is accompanied by egg-laying, oophagy and ejection of larvae by workers competing to lay male (haploid) eggs. Under these conditions, comb destruction and loss of brood can be quite extensive (Free *et al.* 1969; Fisher, unpublished observations), and social parasites may experience decreased reproductive success (Fisher 1983).

Although *P. citrinus* females are capable of suppressing ovarian development in queenless workers of *Bombus impatiens* (Fisher 1984a), the mechanism by which host bees are dominated is unknown. Plath (1922, 1934) observed *P. citrinus* females 'mauling' bees of its two hosts, *Bombus impatiens* Smith and *B. vagans* Smith. Queenless bumble bee workers sometimes maul each other, and queens sometimes maul their workers (Free 1955), presumably when the queen's capability for pheromonal inhibition of ovarian development in workers (van Honk *et al.* 1980) has diminished due to her age or senescence. Dominance hierarchies based on physical pushing, nudging or grabbing have been recorded in a wide variety of social insects, and the separation of physical from pheromonal domination has been used to distinguish less advanced from more advanced social insects (Wilson 1971).

If physical domination is an alternate method of worker domination used by *Psithyrus* females, parasites should be incapable of suppressing ovarian development if they are denied physical contact with host workers. The following experiment was designed to test the importance of physical contact in dominating the host workers, and to observe parasitized colonies to see how parasite behaviours reflect the method of dominating host bees.

Materials and Methods

Ovarian Development in Workers. In order to test the importance of physical contact in the domination of host workers by *Psithyrus* females, I separated newly eclosed (callow) *Bombus impatiens* workers from conspecific queens and from females of *Psithyrus citrinus* by wire screens. This part of the study was conducted in mid July 1983, at a time when the ovaries

of *P. citrinus* females are fully developed (Fisher, unpublished observations). Workers were removed from laboratory colonies, and placed in small wooden boxes (internal dimensions $77 \times 77 \times 25$ mm) held at 30°C . *Psithyrus* females were caught in the field as they searched for host nests, and maintained in small cages with access to sugar water and pollen until they were used for experiments. The boxes were divided vertically in half by 3-mm-gauge mesh wire screen. Each box half was supplied with fresh pollen and sugar water every two days, as well as with a few cocoons which bees could incubate, and on which they could lay eggs. Each box was covered with a glass lid so that bees could not escape or crawl over the screen divider, and could be watched.

Two types of replicate were conducted. In one, 3 callow *B. impatiens* workers were confined on one side of the screen, and a conspecific queen occupied the other side. The second type was identical, except that a *P. citrinus* female occupied one half of the box, and 3 workers the other half. Workers were confined for six days, the minimal time required to reliably detect dominance effects via differential ovarian development (Pomeroy 1981), after which they were removed and frozen. Ovaries were removed later, held in Bouin's fluid (picro-formal-acetic fixative) for at least five days, blotted surface-dry and weighed. Total ovarian weight was measured rather than oocyte length (e.g. Cumber 1949) as it gives a more accurate measure when oocytes are too shrivelled from resorption to be reliably measured. Five *Psithyrus*-containing, and 6 queen-containing replicates were studied.

Behavioural observations. A total of 6 *Bombus vagans*, and 4 *B. impatiens* colonies, were reared in the laboratory from spring-caught queens during the summer of 1983 at Trent University in Peterborough, Ontario (rearing methods: Plowright and Jay 1966; Pomeroy and Plowright 1980). Females of *Psithyrus citrinus* were introduced into each of these colonies, from 19 July - 17 August (introduction methods: Fisher 1984b). Bumble bee colonies contained from 7-50 workers at the time of parasite introduction.

Following the successful introduction of parasites (NOTE: this study does not include the results of other, failed introductions in which parasites were killed or prevented from entering host nests), each colony was observed at 2-day intervals for 15 minutes. During this time period, the behaviour of host bees and parasite females was monitored. Interactions between parasites and host bees (maulings, egg-laying, etc.) were recorded. Of the 10 bumble bee colonies, queens in 2 of 4 *B. impatiens* nests, and in 1 of 6 *B. vagans* nests were killed during parasite introductions. The remaining colonies were occupied by both parasite and host queen, with the exception of one *B. vagans* colony, which was queenless at the time of parasite introduction.

Results

Ovarian analysis. Workers confined beside a *Psithyrus* female had heavier ovaries than those of workers confined beside a conspecific queen (Table I). Dominance hierarchies are established quickly in the absence of a queen, and not all workers undergo ovarian development (Pomeroy 1981). For this reason, only weights of the largest ovaries of workers from each experimental box were included for further statistical analysis. The difference in ovarian weights between the two experimental groups, considering only the largest pair of ovaries from each replicate, was significant ($P < 0.01$, Mann-Whitney U-test).

Dominance behaviour of usurping parasites. Following their introduction into host colonies, *Psithyrus citrinus* females mauled host queens and workers. Mauling consisted of climbing onto the body of a bee, and grabbing it as if to sting, but not actually doing so. Each mauling was very brief (0.5-1.0 second). Following their release by the *Psithyrus* female, host bees almost always moved away from the parasite. Workers occasionally were mauled twice in succession, particularly if they did not move away from the parasite after being mauled the first time.

Table I. Ovarian weights of *B. impatiens* workers confined in experimental boxes, and separated from a queen or *Psithyrus* female by 3mm-mesh screen

Replicate	Ovarian Weight (mg) of Worker (Range)	
	With <i>Psithyrus</i>	With queen
1	4.26 (0.65-6.20)	0.49 (0.33-0.60)
2	8.10 (0.80-13.50)	1.11 (0.40-1.58)
3	1.91 (0.85-3.60)	0.13 (0.10-0.20)
4	4.12 (2.45-7.20)	0.18 (0.10-0.25)
5	5.19 (1.00-9.37)	1.36 (0.93-1.58)
6		3.24 (2.97-3.75)

Similar amounts of mauling behaviour were observed in nests of both *Bombus impatiens* and *B. vagans* (Figure 1). During the first few days that *Psithyrus* females occupied the comb, mauling of host bees occurred often, but subsequently decreased in frequency. Initially, parasites mauled almost every bee with which they came in contact. After 2-3 days on the comb, most bees moved away from the *Psithyrus* female when it approached, and were not mauled. Workers and queens which were mauled by *P. citrinus* females often left the nest, and huddled in the colony's front foraging box. Some of these bees did not return to the nest. In 3 of 4 *B. vagans* nests, and in 1 of 2 *B. impatiens* nests in which the queen survived the introduction of the *Psithyrus* female, host queens left the nest after being mauled by parasites. Three of these queens did not return. Thus, while 3/10 of the parasitized *Bombus* colonies were queenless as a result of queens being killed by parasites, a further three colonies became queenless as a result of queen displacement in the days subsequent to parasite introduction.

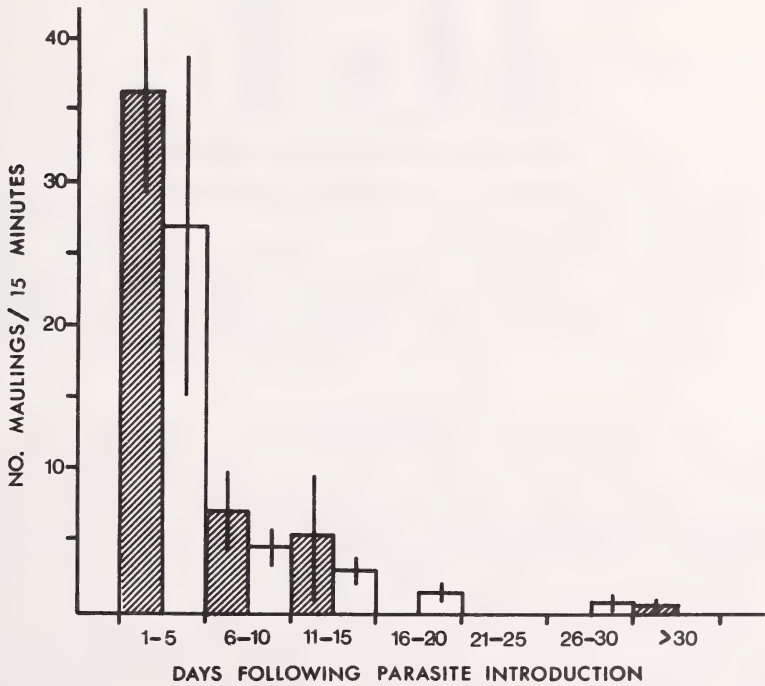


FIG. 1. Mauling frequencies displayed by *P. citrinus* females in parasitized *B. impatiens* (hatched lines) and *B. vagans* colonies. Bar heights represent average number of mauulings observed/observation period; vertical lines SE.

In the three colonies in which queen-parasite cohabitation occurred, queens sometimes were observed at the side of the nest, and off the comb. They usually returned to the comb during the course of the observation period. One queen laid eggs, but these were eaten by the *Psithyrus* female.

In addition to mauling host bees, *Psithyrus* females also rubbed their heads against the bodies of other bees. Head rubbing usually lasted 1-2 seconds. Unlike mauling behaviour, it did not result in displacement of the bee from the area occupied by the *Psithyrus* female. Parasites usually rubbed their heads against the thoracic pile of other bees, although there was considerable variation in the point of body contact. Head rubbing behaviour was not correlated with the period of nest occupation by parasites (Figure 2), nor was it directed at one type of bee. *Psithyrus* females rubbed their heads against host workers, queens, and their own offspring, after *Psithyrus* males and females began to emerge from parasite cocoons.

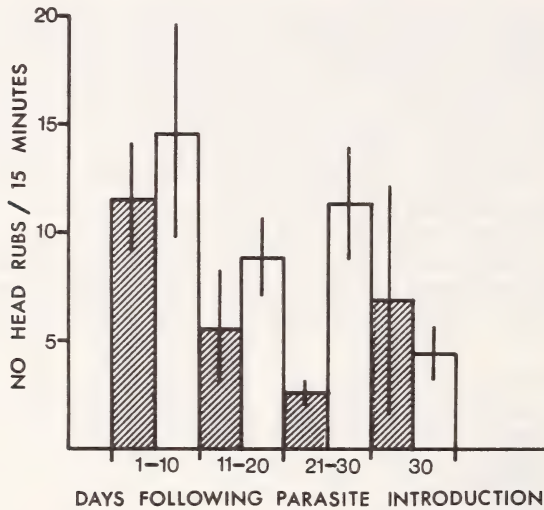


FIG. 2. Head rubbing behaviour displayed by *P. citrinus* females in parasitized *B. impatiens* (hatched lines) and *B. vagans* colonies. Bar heights represent means; vertical lines SE.

Except through these two types of behaviour, parasites had little contact with host bees. Bees that returned to the comb after being mauled incubated parasite cocoons, and fed developing *Psithyrus* larvae. Parasites succeeded in rearing offspring, irrespective of queen presence, in all but one *B. vagans* nest. The *Psithyrus* female in this colony died 23 August without laying eggs.

Discussion

The hypothesis that physical contact is required between a *Psithyrus citrinus* female and host workers, in order to suppress worker ovarian development, is supported by the results of this experiment. The ovarian weights of workers confined beside a *Psithyrus* female are similar to those of workers confined in experimental boxes for similar time periods by themselves (see Fisher 1984a), indicating that *Psithyrus* females separated from workers can exhibit little or no control over worker ovarian development.

It is tempting to conclude that the dominance displayed by *P. citrinus* females is entirely behavioural, and is a result of their mauling host bees. Because the head rubbing exhibited by *Psithyrus* females did not result in displacement of host bees, it is unlikely that it is involved in host dominance. This behaviour may be more important in adopting colony odours than in the domination of host bees (Sladen 1912).

It is possible that parasites deposit a contact pheromone while they maul or rub against their hosts. If parasites can inhibit host worker ovarian development by pheromones, presumably an entirely different mechanism from that displayed by host queens, which use pheromones to continue to dominate workers separated from them by wire screen, is involved. The mandibular glands have been implicated as the source of the dominance signal (van Honk *et al.* 1980), although there may be other anatomical sources (Pomeroy 1981). However, considering the likelihood that bumble bee dominance pheromones are species-specific (Pomeroy 1981), it is unlikely that *P. citrinus* females possess a generalized dominance pheromone which could be used in the nests of a variety of bumble bee species.

Physical dominance by *Psithyrus* of host bees may allow females of the former to parasitize bumble bees in a variety of subgenera. The relationship between host specificity and the dominance abilities of *Psithyrus* females may best be resolved by examining western North American species. *Psithyrus suckleyi* Greene, *P. insularis* Smith, and *P. fernaldae* Franklin are all *Bombus* generalists which often kill or displace host queens (K.W. Richards, personal communication). Unlike *P. citrinus*, the host specificity of which has not been determined, these bumble bee social parasites should be able to dominate queenless workers of a variety of bumble bee species, in different subgenera.

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DEVELOPMENT OF A SECOND GENERATION OF THE ALFALFA WEEVIL, *HYPERA POSTICA* (COLEOPTERA: CURCULIONIDAE), IN EASTERN ONTARIO¹

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Abstract

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Studies on the alfalfa weevil, *Hypera postica* (Gyll.), in eastern Ontario from 1980 - 82 showed that a small but significant portion of the summer adult population matured sexually without a period of aestivation. Reproductive females were detected about 15 days after peak emergence. From mid July to early August in each of the three years, 47, 60, and 20%, respectively, of the active non-parasitized weevils were gravid. Studies of seasonal development indicated that eggs deposited by summer females in late July and early August 1981 were exposed to sufficient heat units to develop through the complete life cycle; it was estimated that one weevil per 0.09m² survived to adulthood. The importance of a partial second generation with respect to survival is discussed.

Introduction

In northeastern North America, the life cycle of the alfalfa weevil, *Hypera postica* (Gyll.), comprises a single brood of larvae in May and June from eggs laid in the spring by overwintered adults (Helgeson and Cooley 1976; Miller and Guppy 1972; Mailloux and Pilon 1975). Larvae known to occur at low levels between midsummer and late fall have been attributed to declining oviposition by old females (Blickenstaff *et al.* 1972; Manglitz 1958; Miller and Guppy 1972), delayed oviposition (Barnes 1967), or oviposition by summer weevils after a period of aestivation (Cothran and Gyrisco 1966; Huggans and Blickenstaff 1964; Manglitz 1958; Miller and Guppy 1972). The fate of these is not known.

There is general agreement that summer weevils disperse from alfalfa and aestivate, and according to Prokopy and Gyrisco (1965), dispersal in New York may be as early as 14 days after emergence. Surgeoner and Ellis (1976) noted that adults in southern Ontario remained in alfalfa for a more lengthy period before aestivation, whereas Southwick and Davis (1968) reported that weevils in Utah remained active in alfalfa and neither aestivated nor became reproductive between emergence in early July and hibernation in winter. However, in California 1-2% of the summer adults of the closely related species, *H. brunneipennis* (Boheman), laid eggs without a period of diapause (Fisher *et al.* 1961).

During the course of studies on parasitism of adult weevils in eastern Ontario in 1980, it was noted by one of us (C.C.L.) that a few summer weevils became gravid shortly after emergence. This prompted more detailed observations on ovarian development which showed that a portion of the adults matured sexually without aestivation and produced a small second generation. Details of their development and the significance of a second brood as a survival mechanism in the life system of the alfalfa weevil are discussed.

Materials and Methods

This investigation was conducted at 2 sites in southern Ontario, at Moira in the Bay of Quinte area (described by Harcourt *et al.* 1977) and the Kemptville area near Ottawa. During 1980-82, collections of adults were made weekly, from peak emergence in early July through October, by sweeping alfalfa foliage with a standard insect net during midday and at dusk. Summer adults, viz. first-generation weevils emerging in late June and early July, were separated from overwintered weevils by their pale brown colour and heavily scaled elytra.

¹Contribution No. 737.

Fall adults, viz. teneral adults of the second generation emerging in September and October, were identified by their soft integument. Dissections of female weevils soon after capture enabled us to categorize the ovaries into the following developmental stages as adapted from Snow (1928): *small*, lack of development; *medium*, ovarian tubules enlarged with or without segmentation; and *large*, referred to here as the gravid stage.

Larval populations were monitored at Kemptville in 1981 using the sampling techniques described by Guppy *et al.* (1975) to obtain detailed population estimates; numbers of feeding larvae were recorded in 20, six-stem bouquets of foliage taken weekly during August and September. In 1982, larval development was determined from catches in the weekly sweep-net collections.

Results

Field activity of summer adults

Examination of specimens collected just after the peak of emergence in July showed that less than 1% of the population was composed of old adults. Therefore, dilution of the summer adult population was of little significance in the present study. This was not surprising in view of the almost total mortality of old adults due to parasitism by *Microctonus aethiopoulos* Loan in late May and early June each year.

In agreement with previous reports on diel behaviour, activity was greatest at dusk (Poinar and Gyrisco 1960; Southwick and Davis 1968; Warner and Ritcher 1974) and each year there was a decrease in field populations of the adults throughout July. A sharp fall always occurred 10 to 14 days after peak emergence, and was followed by a more gradual decline. Some of the weevils developing reproductively may have moved from uncut fields to regrowth alfalfa, however, the decline was attributable largely to adults about to aestivate, including both parasitized and unparasitized summer adults.

Sexual development

During each of the three years, approximately 500 females were dissected from early July through September; about half of these were parasitized by *M. aethiopoulos* and *M. colesi* Drea. The status of ovary development in unparasitized weevils during July and early August is shown in Fig. 1; this period is critical to a second generation because eggs deposited later in the season would not receive sufficient heat to complete the life cycle. In 1980, gravid females were first noted in mid July, 18 days after peak emergence; and in 1981 and 1982, they were detected about 15 days after the peak. In the three years, percentages in the gravid stage from mid July to early August were 47, 60 and 20, respectively. After the first week of August, 70 to 100% of the active non-parasitized females were gravid; by mid September it was no longer possible to determine whether or not the specimens had aestivated.

Development of the second generation

Seasonal development of the second generation at Kemptville, in relation to heat units (base 9°C) accumulated from 1 April, is shown in Table I. In 1981 and 1982, gravid females began to appear in the population during the third week of July; eggs were not monitored but, based on the thermal requirements for hatch (113°D₉) (Guppy and Mukerji 1974) and records of the first larvae, oviposition began about 26 July and 9 August in the two years, respectively. Peak larval numbers were recorded on 2 September 1981, more than two weeks earlier than in 1982; however, degree-day accumulations were similar for that event in both years. Fall adults were detected during the first week of September 1981.

The larval counts at Kemptville in 1981 (Table II) indicated that a significant portion of the eggs laid in late July and August would have sufficient time to complete their life cycle. Using thermal requirements for development of larvae and pupae (Harcourt 1981; Guppy and Mukerji 1974) and heat-unit accumulations from 1 April to freeze-up, it is possible to draw

horizontal lines through Table II to project the number of weevil larvae that would have had time to pupate and reach adulthood. This is a small proportion of the larval population but parallel life table studies by one of us (D.G.H.) showed that only 70 percent of the cocooned stages were killed by frost. In 1982, larval density was similar to that in 1981; however, heat-unit accumulations in late August and September were insufficient to allow more than an occasional individual to reach the adult stage.

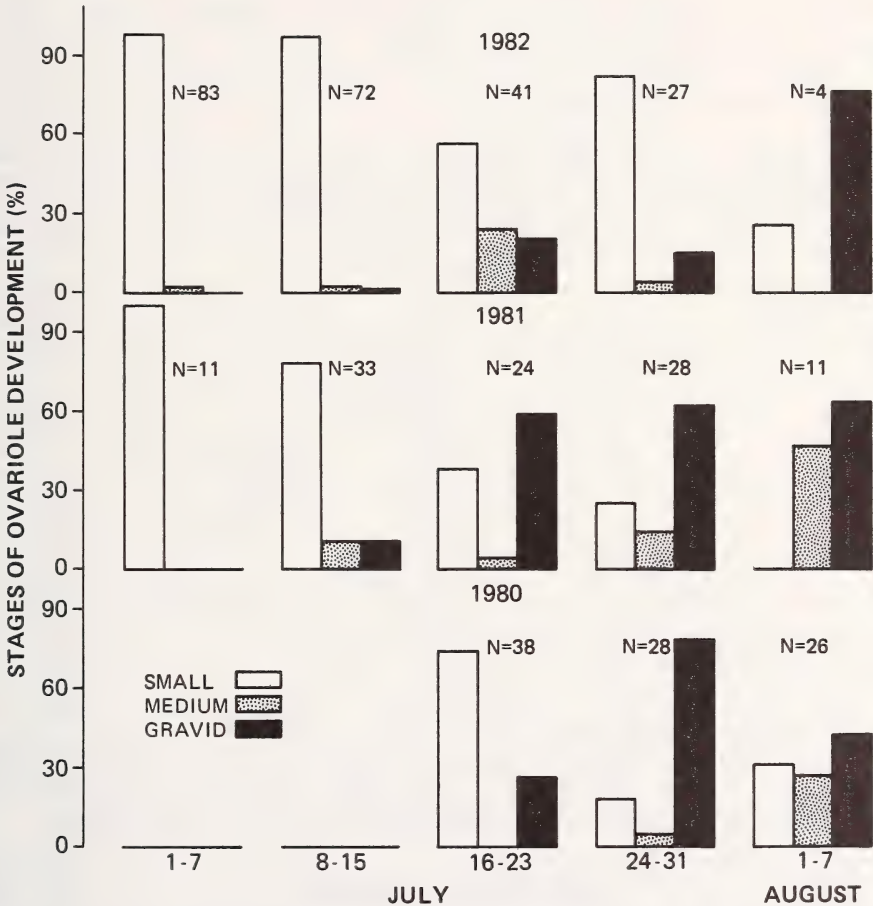


FIG. 1. Status of ovariole development in non-aestivating summer females of *Hypera postica* during July and early August in eastern Ontario, 1980-82.

Table I. Seasonal occurrence of second-generation stages of *H. postica* in relation to heat units,^a Kemptville, Ontario

Stage	1981		1982	
	Date	°D ₉	Date	°D ₉
Gravid females	July 20	720	July 19	672
First larvae	Aug 3	851	Aug 24	982
Peak larvae	Sept 2	1147	Sept 20	1150
Fall adults	Sept 4	1159	-	-

^aHeat-unit accumulations (°C) began 1 April.

Table II. Numbers of weevil larvae in 120 stems of alfalfa, Kemptville, Ontario, 1981. Number of heat units^a above a threshold of 9°C were sufficient for those above the line to reach adulthood

Date	Instar			
	I	II	III	IV
Aug 19	8	3	8	2
25	26	40	28	10
28	61	29	19	8
Sept 2	71	72	37	24
9	70	47	30	48
14	21	24	18	32
21	8	17	23	44

^aHeat-unit accumulations began 1 April.

Mortality in the second generation

Frost was the main mortality factor in the second generation. There was no evidence of insect parasites in either 1981 or 1982, but fungus disease caused by *Erynia* spp. (= *Entomophthora*) (Harcourt *et al.* 1981) killed some of the larvae in both years.

Discussion and Conclusions

In eastern Ontario during 1980-82, populations of female weevils in early July were composed of individuals maturing sexually and those about to enter a period of aestivation. By mid July, dispersal from feeding sites caused a sharp decrease in the numbers of weevils at the sampling sites; however, a small proportion remained and most of the unparasitized females collected in late July and August were reproductive. Non-aestivating summer adults became gravid within 2 to 4 weeks of emergence; this duration was similar to the maturation time for reared weevils as reported by Bland (1971). Eggs were laid from July to freeze-up and formed a discrete population because the almost total kill of overwintered adults by *M. aethiopoidea* in late May and early June prevented much overlap of generations.

Fig. 2 portrays our version of the seasonal history of the alfalfa weevil in eastern Ontario. Although numbers of eggs deposited by summer adults are small relative to those laid by the main brood in spring, in some years the proportion reaching adulthood may form a substantial part of the total overwintering population. For example, life tables for the second generation at Kemptville in 1981 showed that one weevil per 0.09 m² survived to adulthood. Based on life table data for the first generation in nearby plots, this represented at least a third of the total population entering hibernation.

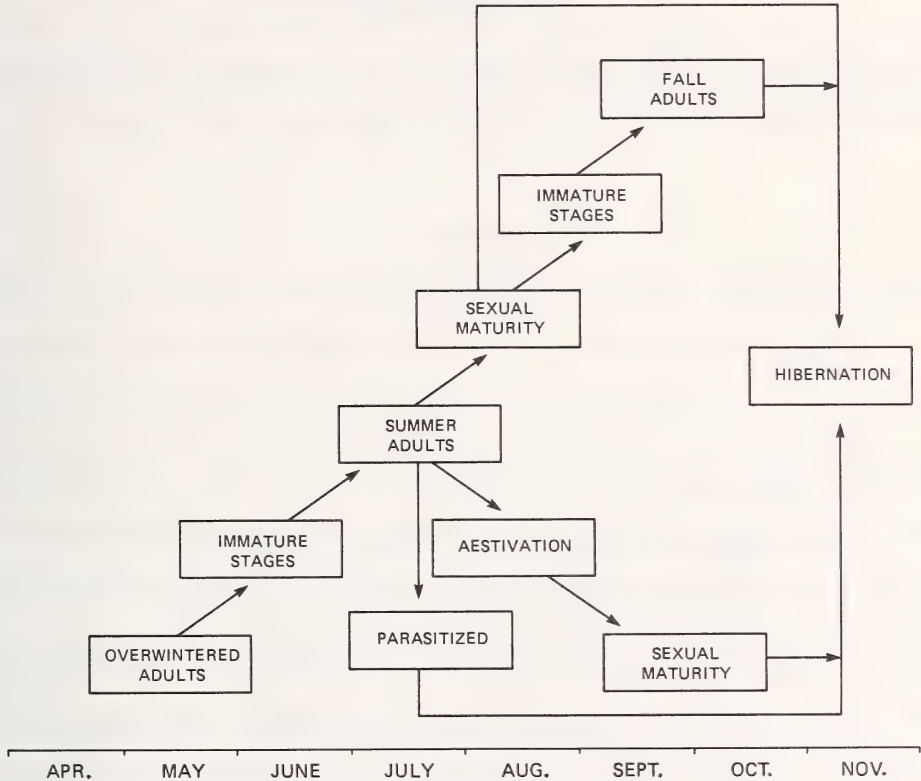


FIG. 2. Generalized seasonal history of *Hypera postica* in eastern Ontario.

Natural selection for a non-aestivating strain of the weevil may have occurred as a result of continuous pressure from disease outbreaks and the high rates of attack by *Microctonus* spp. These organisms confer an advantage to weevils that develop very early in the season. Early adult activity in spring reduces the chances of sterilization by *M. aethiopoides*, and larvae that hatch early, viz. by the middle of May, have a greater opportunity than later cohorts to escape the ravages of disease epizootics, parasitism by *M. colesi* and in addition, the management strategy of early harvest. This segment of the population may be expected to complete its feeding by early June and to produce adults by early July.¹ Those adults remaining active would be sexually mature sufficiently early in the summer to produce a second generation.

¹ The trend towards early seasonal development is supported by population data from the Quinte area which show that the rate of egg deposition in the litter has increased significantly since the early 1970's.

Development of a partial second generation has important ramifications with respect to weevil survival. In late summer, larval parasites are rare and rates of disease are low, giving the population a higher probability of success. Fall adults enter winter at a younger age than their summer counterparts and having escaped the rigors of summer/fall survival, may be better fit and more fecund in spring.

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PARASITES OF THE POTATO STEM BORER, *HYDRAECIA MICACEA* (LEPIDOPTERA: NOCTUIDAE)

by

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Abstract

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Among collections of *Hydraecia micacea* (Esper) from corn fields near Guelph, Ontario from 1981 to 1983, as many as 61% of larvae were parasitized by *Lydella radialis* (Townsend) (Diptera: Tachinidae). *Diadegma* sp., *Campoletis* sp., *Glypta* sp., *Pterocormus* sp. and *Therion* sp. (Hymenoptera: Ichneumonidae) also were recovered at incidences ranging from 0.5 to 6.0%. All parasites reared from the Guelph area were new host records. Larvae of *H. micacea*, collected in Europe in 1982 and imported to Canada, were parasitized by *Lydella stabulans* Fall. at rates as high as 57.1%. The parasites, *Macrocentrus blandus* Eady and Clark (Hymenoptera: Braconidae), a species of Mermithid (Nematoda), and *Exephanes occupator* Grav. (Hymenoptera: Ichneumonidae), were also recovered from European collections at incidences below 10%.

Males of *L. radialis* were distinguished from *L. stabulans* by the relative sizes of sturmia spots, cerci and surstyli whereas ratios of length of antennal segments distinguished the females. Mating duration and adult male longevity of *L. radialis* was significantly greater than that of *L. stabulans*. Adult female longevity for both species averaged 3 weeks and their fecandity was similar. Larval development was significantly longer for *L. radialis* (113°D_{13.5}) than for *L. stabulans* (159°D_{6.7}). Pupal development was similar for the two species with males developing faster than females. Neither species developed successfully on larvae of *Ostrinia nubilalis* (Hübner) (European corn borer).

M. blandus was reared for several generations in the laboratory. Mating occurred on emergence, gestation was 1 day and adult longevity averaged 4 to 5 days. Fecundity of virgin females averaged 90 eggs. Pupation occurred within 1 to 2 days after larval emergence. Thermal constants and developmental thresholds for pupal development were 268°D_{4.9} for males and 245°D_{6.4} for females.

Introduction

The potato stem borer (PSB), *Hydraecia micacea* (Esper), erroneously spelled '*Hydroecia micacea*' in most North American literature, has become a pest of corn, rhubarb and potato in eastern Canada since its introduction from Europe to Nova Scotia in the early 1900s (Deedat *et al.* 1983). Since insecticides have not effectively controlled PSB (Deedat *et al.* 1982), the potential of native and foreign parasites in regulating PSB populations deserves consideration. However, parasites of the PSB must first be identified and their life histories understood before biological controls can be implemented. North American records of PSB parasites are restricted to the egg parasites, *Telenomus* sp. (Hymenoptera: Scelionidae) (Jobin 1963), *Trichogramma retortidum* (Girault) (Hymenoptera: Trichogrammatidae) and *Centrodora near locustrum* Girault (Hymenoptera: Mymaridae) (Deedat *et al.* 1983). European records include the parasites, *Lydella stabulans* Meig. (Diptera: Tachinidae), *Epirus* sp. (Hymenoptera: Ichneumonidae), *Macrocentrus infirmus* Nees (Hymenoptera: Braconidae), a species of Mermithid (Nematoda), and *Exephanes occupator* Grav. (Hymenoptera: Ichneumonidae) (Zwölfer 1962).

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This paper discusses the incidence of parasitism of PSB populations collected in Ontario from 1981 to 1983 and in Europe in 1982. Laboratory studies on the life histories of parasites potentially useful to controlling PSB populations are also described. Parasites studied are *Lydella radialis* (Townsend), *L. stabulans* Fall. and *Macrocentrus blandus* Eady and Clark. With the exception of host-parasite records (Thompson 1951; Arnaud 1978), little is known of the biology of the two *Lydella* species. Existing knowledge on the biology of *M. blandus* (= *M. near infirmus* Nees) is restricted to the work of Zwölfer (1962) who reared this parasite from one PSB larva and from several larvae of *Hydraecia petasitis* Dbl. collected in Europe in 1961.

Materials and Methods

Incidence of parasitism. Mature PSB larvae and pupae were collected in June and July from corn fields near Guelph, Ontario (43°34' N, 80°16' W) in 1981, 1982 and 1983 and near Fergus, Ontario (43°43' N, 80°24' W) in 1982. Mature PSB larvae were collected in May and June 1982 near Basel, Switzerland (47°33' N, 7°35' E) (Istein, West Germany; Leymen, France and Bettendorf, France) and near Husum, West Germany (54°29' N, 9°04' E), imported to Canada and reared in quarantine at the University of Guelph. All PSB were reared on artificial diet (West 1984) until death or pupation occurred. The incidence of parasites emerging from dead hosts was noted.

Lydella spp.

Laboratory colonies of *L. radialis* and *L. stabulans* were established using individuals reared from late-instar PSB collected, respectively, from corn fields near Guelph in 1982 and 1983 and Husum, West Germany, in 1982. Pupae were transferred to petri dishes (10 × 1.5 cm) containing moistened vermiculite and held at 23°C (16:8 L:D) until emergence. Adults were held in the laboratory¹ in screened plexiglass cages (30 × 30 × 30 cm) lined with paper towels and provided with granulated sugar and water. Cages were misted daily. *Lydella* larvae were dissected from gravid females and transferred in groups of 5 to intersegmental membranes of sixth-instar PSB. Hosts were maintained on artificial diet (West 1984). Several generations of *Lydella* were reared.

The external morphology of adult *L. radialis* and *L. stabulans* was examined to determine characters useful in distinguishing the two species.

To observe the duration of mating, individual pairs of adults were removed *in copula* within 5 minutes of the time of mating and transferred to small cages (12.5 × 18.0 × 6.0 cm). Mating pairs were continuously observed until copulation ceased. The longevity of adults, mated within 5 days of emergence, was observed. Fecundity was determined by dissecting mated females 12 days or more after mating and counting the number of fertilized and unfertilized eggs present. An egg was counted as fertilized if it contained a larva with developed mouth hooks.

Threshold temperatures (t) and thermal constants (K) required for the larval and pupal stages were determined by linear regression analysis (Arnold 1959). Standard errors of t and K were determined following the method of Campbell *et al.* (1974). *Lydella* were reared at 17°, 21°, 23°, 25° and 27°C (± 0.5°C) under a photoperiod of 16:8 L:D. The occurrence of pupation and emergence was checked twice daily.

The suitability of the European corn borer (ECB), *Ostrinia nubilalis* (Hübner), as an alternative host for both *Lydella* species and the hop vine borer (HVB), *Hydraecia immanis* Guenée, as a host for *L. stabulans* was investigated. Groups of 4 first-instar *Lydella* dissected

¹Laboratory conditions, hereafter referred to as 'standard', were approximately 23°C and 16:8 L:D. Adults were exposed to sunlight entering through west-facing windows.

from gravid females were transferred to the bodies of mature ECB larvae whereas a group of either 4 or 9 were transferred to mature HVB larvae. Hosts were reared on artificial diet (West 1984) at 23°C. Dead hosts and hosts still alive and in the larval stage after 2 months were dissected in order to recover any developing *Lydella*. ECB larvae (London strain) were obtained from Agriculture Canada, London, Ontario. HVB larvae were collected from a corn field near Rankin, Ontario in June 1983.

Macrocentrus blandus

A laboratory colony of *Macrocentrus blandus* was established with individuals reared from parasitized PSB collected in Leymen, France in 1982. Several generations were reared under standard laboratory conditions. Larvae of *M. blandus*, on emergence from PSB, were transferred to petri dishes (3.5 × 1.0 cm) where pupation occurred. Each petri dish contained pieces of Kimwipe® which served as a support for the spinning of pupal cocoons. On eclosion adults were sexed and transferred to screened plexiglass holding cages (30 × 30 × 30 cm) which were misted and streaked with 10% honey solution daily. To encourage parasitization, mated females in groups of 5 to 10 were confined for 24 hours in petri dishes (1.5 × 9.0 cm) containing first- to fourth-instar PSB. The petri dishes were lined with moistened circles of filter paper and their lids streaked with 10% honey solution. Cut stems of seedling corn were provided as food for PSB. PSB, after exposure to possible parasitization were reared on artificial diet until death or pupation occurred.

The mating duration of newly emerged adults in the holding cages was observed. In order to determine longevity, adults were transferred to cages with other individuals of the same age and monitored daily. These cages (30 × 30 × 30 cm) were maintained as were the holding cages but also were provided with numerous stems of seedling corn containing first- to fourth-instar larvae of *H. micacea*. Fecundity was estimated by counting eggs dissected from virgin females. Threshold temperatures and thermal constants required for pupal development were determined as described previously. Pupae were reared at 17°, 19°, 21°, 23°, and 25°C (± 0.5°C) under a photoperiod of 16:8 L:D. The occurrence of emergence was checked twice daily.

Results and Discussion

Incidence of parasitism

Ontario. Four parasites were reared from PSB larvae: *Lydella radialis* Townsend (Diptera: Tachinidae); and *Diadegma* sp., *Campoletis* sp. and *Glypta* sp. (Hymenoptera: Ichneumonidae) (Table I). Two parasite species were reared from pupae and identified as *Pterocormus* sp. and *Therion* sp. (Hymenoptera: Ichneumonidae) (Table I). *Pterocormus* sp. was reared from only one pupa while the *Therion* sp. was reared from several PSB collected as larvae or pupae. There are no previous records of any of these parasites attacking PSB.

Lydella radialis parasitized between 25 and 61% of PSB collected from the Guelph site (Table I). Higher rates of parasitism were observed later in the season in each year studied. Such a phenomenon may be due to later emergence of the parasite in the spring and/or a tendency for the larval stage of the parasitized host to be abnormally prolonged. However, these factors were not investigated. The absence of *Lydella* at Fergus may be due to a lack of alternate hosts. Although as many as 8 *L. radialis* were recovered from one host, the number generally obtained was one or two (Table II). The sex ratio of *L. radialis* reared (n=231 adults) favoured females by 1.3 to 1 in 1983.

The incidence of the 3 ichneumonid species was less than 6% for all collections, and no species was recovered in all years of collecting (Table I). Given that the genera involved attack a large number of lepidopterous species (Krombein *et al.* 1979), they probably are incidental parasites of the PSB.

Table I. Percentage parasitism of *Hydraecia micacea* collected as mature larvae and pupae from corn fields in Guelph and Fergus, Ontario, 1981-83

Location	Date of collection	No. of <i>H. micacea</i> collected	<i>Lydella</i> sp. (%)	<i>Therion</i> sp. (%)	<i>Diadegma</i> sp. (%)	<i>Campoplexis</i> sp. (%)	<i>Pterocormus</i> sp. (%)	<i>Glypta</i> sp. (%)
Guelph	24-VI-81	144	1.3	—	—	—	—	—
	25-VI-81	174	7.5	—	—	—	—	—
	26-VI-81	48	23.0	—	—	—	—	—
	30-VI-81	23	43.5	—	—	—	—	—
	3-VII-81	39	61.5	—	—	—	—	—
	21-VI-82	55	5.5	—	—	—	—	1.8
	23-VI-82	115	5.2	—	—	—	—	—
	30-VI-82	74	17.6	—	—	—	—	—
	7-VII-82	4	25.0	—	—	—	—	—
	23-VI-83	29	3.4	—	—	—	—	—
	28-VI-83	102	5.9	—	—	—	—	—
	30-VI-83	95	7.4	—	—	—	—	—
	5-VII-83	198	21.8	1.5	—	—	—	—
	8-VII-83	197	44.2	1.0	—	—	0.5	—
	12-VII-83	46	47.8	2.2	—	—	—	—
	15-VII-83	17	41.2	5.9	—	—	—	—
Fergus	18-VI-82	285	—	—	—	1.4	—	—
	25-VI-82	158	—	—	0.6	0.6	—	—
	2-VII-82	49	—	—	—	—	—	—
	9-VII-82	17	—	—	—	—	—	—

Table II. Number of *Lydella*¹ reared from *Hydraecia micacea* collected in Ontario and Europe

Year of collection	Area of collection	Number of hosts	Number of <i>Lydella</i> recovered	Average number of <i>Lydella</i> per host $\pm$ S.E.	Range in number of <i>Lydella</i> per host
1981	Guelph, Ont.	60	86	1.43 $\pm$ 0.10	1-5
1982	Guelph, Ont.	23	39	1.70 $\pm$ 0.20	1-4
	Basel, Switz.	70	113	1.61 $\pm$ 0.10	1-4
	Husum, GDR	96	168	1.75 $\pm$ 0.11	1-6
1983	Guelph, Ont.	173	285	1.65 $\pm$ 0.10	1-8

¹*L. radialis* collected in Ontario.*L. stabulans* collected in Europe.

Europe. In the Basel area, no PSB were found on crops and populations were located only in uncultivated areas. Third and fourth instars of PSB were found in stems of reed canary grass, *Phalaris arundinaceae* L., but later instars were found feeding within the stems and roots of meadowsweet, *Filipendula ulmaria* (L.), which has not been reported previously as a host. In the area of Husum, PSB were recovered only from corn.

L. stabulans parasitized as many as 57% of PSB larvae collected in the Basel area and represented the only parasite recovered in Husum where it had an incidence of 25.7% (Table III). The only reported record of the incidence of *L. stabulans* parasitizing *H. micacea* in

Europe is that of Zwölfer (1962), based upon the dissection of 41, and rearing of 43 host larvae collected at Istein on 7 June 1961. Zwölfer obtained only 2 *Lydella* from this collection and suggested an overall rate of parasitism of 2 to 5%, however, had samples been collected later in June these might have yielded a higher incidence of *Lydella*. Results from the present study indicate that *Lydella* is a more important parasite of the PSB in Europe than was previously observed.

Table III. Incidence of parasitism of larvae of *Hydraecia micacea* collected in Europe, May to June 1982

Area of collection	Date of collection	No. of <i>H. micacea</i> collected	<i>Lydella stabulans</i> (%)	<i>Macrocentrus blandus</i> (%)	<i>Exephanes occupator</i> (%)	<i>Mermithid</i> sp. (%)
Leymen, France	29-V	20	—	5.0	—	—
	6-VI	21	38.1	9.5	—	—
	8-VI	14	57.1	7.6	—	—
	9-VI	57	40.4	3.5	—	3.5
	13-VI	48	39.6	6.3	—	—
	20-VI	4	50.0	—	—	—
Bettendorf, France	23-V	10	10.0	—	—	—
	30-V	20	—	—	—	—
	5-VI	3	—	—	33.3	—
	13-VI	4	50.0	—	—	—
Istein, GDR	8-VI	17	41.2	—	—	—
Husum, GDR	30-VI	374	25.7	—	—	—

The number of *L. stabulans* reared per host was usually 1 or 2 as was observed for *L. radicans*, but as many as 6 were recovered (Table II). The sex ratio of individuals reared from field-collected PSB favoured males in the collections from the vicinity of Basel (n=54 adults) by 1.35 to 1 and Husum (n=148 adults) by 1.02 to 1.

*Macrocentrus blandus*² was reared from PSB larvae at incidences between 3.5 and 9.5% in the majority of collections from Leymen, France (Basel vicinity) but was not found elsewhere (Table III). Zwölfer (1962) reared *Macrocentrus* only once from PSB but found it to be the dominant parasite of *Hydraecia petasitis* in the Basel area in 1961. In the present study, the number of larvae of *M. blandus* reared per PSB was high and often exceeded 100.

Only one specimen of *Exephanes occupator* was reared (*ex pupa*) from all PSB collected (Table III). This was unexpected since *E. occupator* was reared at incidences as high as 55% from PSB collected at Istein in 1961 by Zwölfer (1962).

An undetermined species of Mermithid was recovered from 2 of 57 PSB collected on 9 June at the Leymen site (Table III). Zwölfer (1962) frequently reared a Mermithid from *Hydraecia petasitis* but did not find it parasitizing PSB. The low incidence of the Mermithid suggests that it is an incidental parasite and probably not specific to PSB.

Lydella spp.

Morphology. Characters used to distinguish *L. stabulans* from *L. radicans* were the sturmia spot, cerci and surstyli for males and second and third antennal segments for females (Figs.

²The initial determination of *M. infirmus* by Zwölfer (1962) was made before the revision of the genus by Eady and Clark (1964). Specimens of *Macrocentrus* reared from the PSB by Zwölfer were re-identified as *M. blandus* Eady and Clark by the British Museum of Natural History (BMNH). However, *M. infirmus* remains a valid species and a possible parasite of the PSB (T. Huddleston, BMNH, pers. comm. 1982).

1, 2). The sturmia spot, a darkened area on each ventral side of the fourth abdominal segment, always was less than one-half the length of the segment for *L. radicis* (Fig. 1a) but covered more than two-thirds the length of the segment for *L. stabulans* (Fig. 1b). The surstyli were as broad as the cerci in profile in *L. radicis* (Fig. 2a) but comparatively narrower in *L. stabulans* (Fig. 2b). For females, the length of the second antennal segment was generally less than one-half that of the third antennal segment for *L. radicis* (Fig. 1c) but more than one-half for *L. stabulans* (Fig. 1d). Ratios of the lengths of second to third antennal segments were significantly different ($P < 0.0001$)³ between the two species ranging from 0.280 – 0.522 in *L. radicis* ($n = 35$, $\bar{x} = 0.443 \pm 0.008$) and from 0.402 – 0.615 in *L. stabulans* ($n = 42$, $\bar{x} = 0.542 \pm 0.007$).

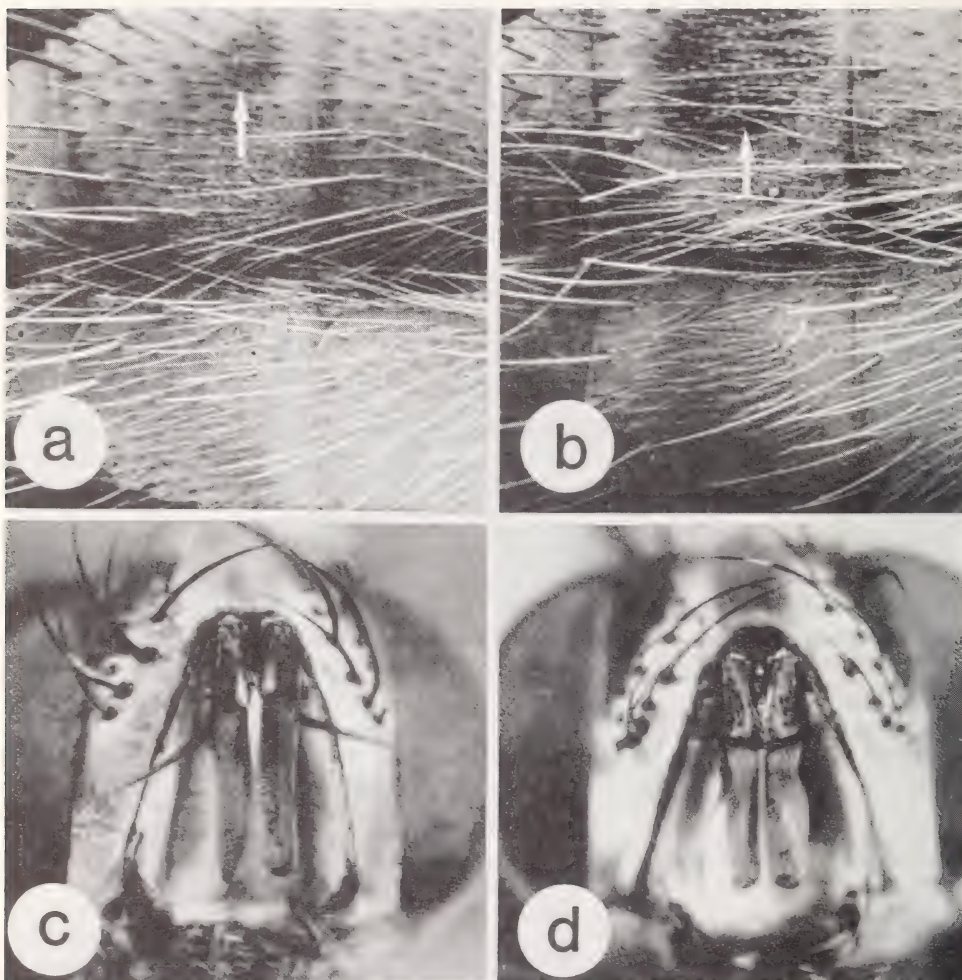


FIG. 1. Morphological characters distinguishing adults of *Lydella radicis* and *L. stabulans*. Sturmia spot (arrow) of *L. radicis* (a) and *L. stabulans* (b); second and third antennal segments of *L. radicis* (c) and *L. stabulans* (d).

³Student's t-test.

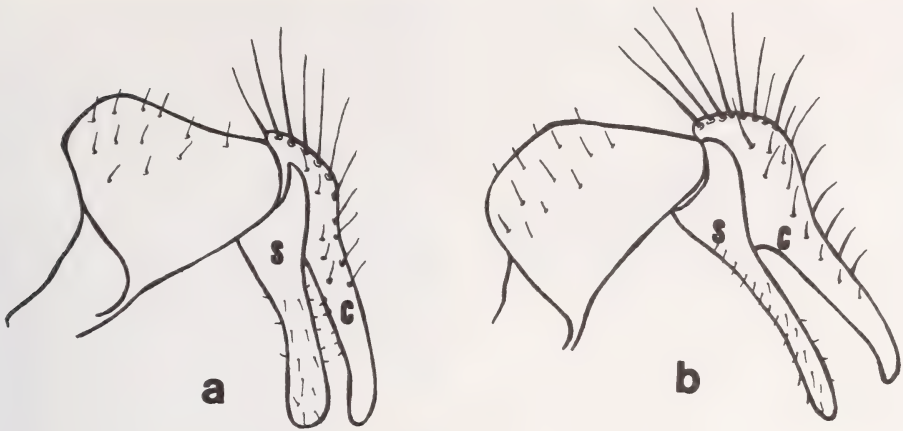


FIG. 2. Left cercus (C) and surstylus (S) of *L. radialis* (a) and *L. stabulans* (b).

Life stages. The life stages of *L. radialis* (Fig. 3) and *L. stabulans* were similar to those described for *Lydella thompsoni* Herting (= *L. stabulans grisescens* R.D.), a parasite of the European corn borer (Baker *et al.* 1949). Adults mated (Fig. 3a) soon after emergence and females, after a preovipositional period of at least 10 days, would larviposit on the host or in its frass if presented with open petri dishes containing mature PSB larvae feeding on corn stems. First-instar larvae (Fig. 3b) entered folds in the host's integument (Fig. 3c) using their rasping mouth hooks to gain entrance to the haemocoel. This process required from 5 to 60 min. Development in the host was rapid with third-instar larvae emerging in about 2 weeks (Fig. 3d). Hosts never survived, dying 1 to 2 days before larval *Lydella* emerged. Puparia formed within 12 hours of emergence of larvae from the host (Fig. 3d) and the pupal period lasted about 2 weeks. Larvae failing to form puparia within 12 hours died.

Mating, longevity and fecundity. Mating usually occurred in the afternoon and was most frequent on sunny days. Fifty-six percent of *L. radialis* (n=72 males, 104 females) and 51% of *L. stabulans* (n=47 males, 64 females) mated within 5 days of emergence. Pairs were not observed to mate a second time. Mating duration ranged from 15 to 245 min for *L. radialis* and 8 to 84 min for *L. stabulans* (Table IV). Mean mating duration for *L. stabulans*, at 45 min, was significantly different to the mean of 70 min observed for *L. radialis* (Table IV).

Both sexes of *L. radialis* lived from a few days to 2 months (Table IV). Male *L. stabulans* lived from 2 to 19 days whereas females of this species lived 8 to 40 days (Table IV). The mean longevity of the two species was significantly different for males (15.8 days, *L. radialis*; 9.1 days, *L. stabulans*), but not for females (21.4 days, *L. radialis*; 19.6 days, *L. stabulans*) (Table IV).

Total fecundity of *L. radialis* ranged from 74 to 691 eggs and averaged 280 eggs (78% fertile) (Table IV). Total fecundity of *L. stabulans* ranged from 86 to 505 eggs, averaged 260 eggs (88% fertile) and was not statistically different from that of *L. radialis* (Table IV). *L. stabulans* had a significantly greater number of unfertilized eggs than *L. radialis* (Table IV). This observation may, however, have been a result of the method used to determine fertility. Although eggs present at the time of mating may have developed into recognizable larvae, those eggs formed, and fertilized, after mating may not have matured to a stage where mouth

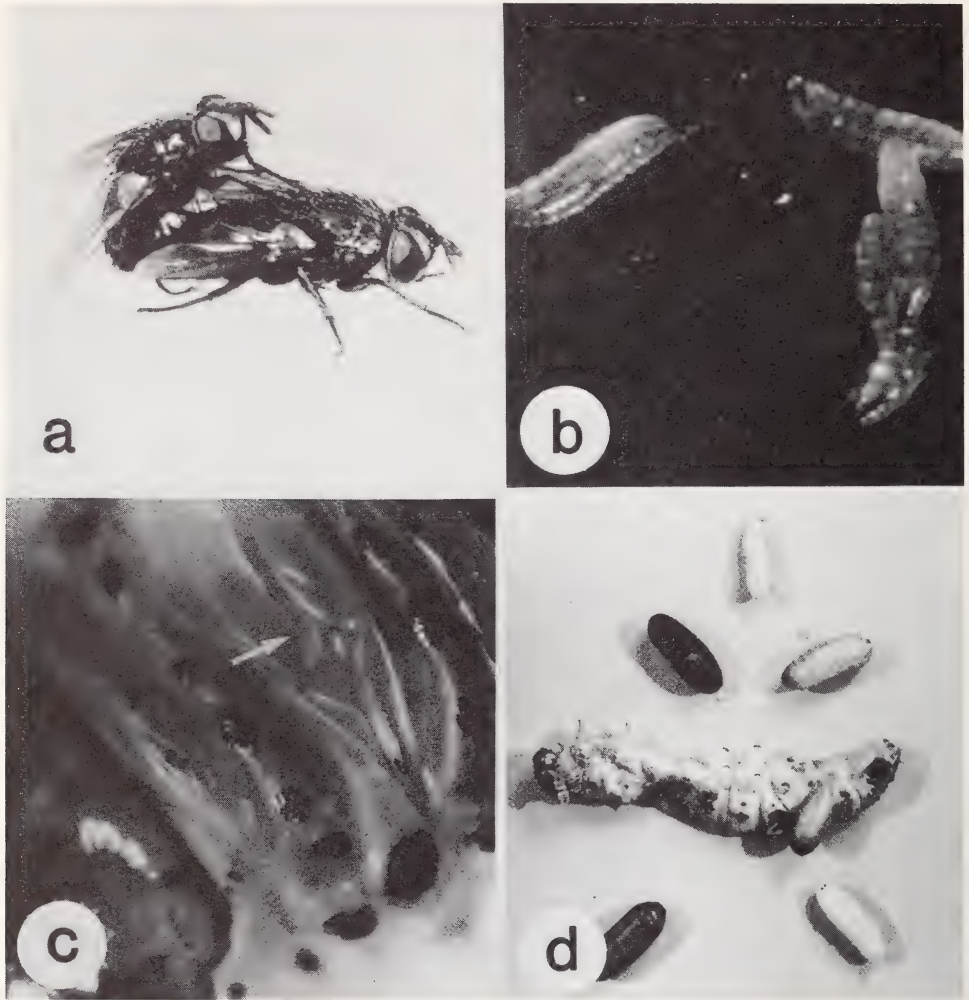


FIG. 3. Life stages of *Lydella radialis*: mating adults (a), first-instar larvae (b), first-instar larva (arrow) entering host (c), dead host surrounded by pupae and mature larvae (d).

hooks were observed. Thus, using the presence or absence of a larva with developed mouth hooks in an egg to determine fertility may result in underestimates. Twelve days for *L. radialis* and 10 days for *L. stabulans* fulfilled gestation requirements although some unfertilized eggs (or immature, fertilized eggs) were always found in mated females at these ages.

Rates of larval and pupal development. In both species marked decreases in developmental rates were observed with a 10°C drop in temperature (Table V). Unlike *L. radialis*, larval development at 27°C for *L. stabulans* was slower than at 25°C suggesting that the optimal temperature for larval development is lower for *L. stabulans* than for *L. radialis*. At all temperatures examined except 27°C, larval development of *L. stabulans* was significantly faster than that of *L. radialis* (Table V). The rate of pupal development was similar for the

two species although development of females at 17° and 25°C and males at 23° and 25°C was significantly faster for *L. stabulans* (Table V). Since males developed faster than females by 1 to 2 days at all temperatures (Table V), developmental thresholds and thermal constants for emergence were determined separately for each sex.

Table IV. Mating duration, adult longevity and fecundity¹ of *Lydella radialis* and *L. stabulans*

Parameter	Species	Number examined	Mean±S.E.	Range
Mating duration (min.)				
<i>L. radialis</i>		34 pairs	70.0±7.6 ^a	15-245
<i>L. stabulans</i>		33 pairs	44.8±3.1 ^a	8-84
Adult longevity (days)				
<i>L. radialis</i> males		45	15.8±2.1 ^{a*}	2-59
<i>L. radialis</i> females		44	21.4±1.4 [*]	7-60
<i>L. stabulans</i> males		23	9.1±0.8 ^{a*}	2-19
<i>L. stabulans</i> females		28	19.6±1.6 [*]	8-40
Fecundity				
<i>L. radialis</i>		22		
fertilized eggs			216.7±37.5	11-691
unfertilized eggs			61.4±13.8 ^a	0-236
total no. of eggs			278.1±34.2	74-691
<i>L. stabulans</i>		36		
fertilized eggs			228.2±15.7	26-401
unfertilized eggs			30.6±5.2 ^a	0-142
total no. of eggs			258.8±16.1	86-505

^{a*}Denotes a significant difference ($P < 0.05$) between species^a, and between sexes* (Student's *t*-test, using Satterthwaite's approximation where variances were unequal).

¹Only the fecundity of mated females was examined.

Thermal constants and developmental threshold for *L. radialis* were 113°D_{13.5} for larvae, 193°D_{6.5} for male pupae and 194°D_{7.9} for female pupae (Table VI). For *L. stabulans* they were 159°D_{6.7} for larvae, 184°D_{6.6} for male pupae and 190°D_{7.4} for female pupae (Table VI).

Since *L. stabulans* develops faster and has a lower developmental threshold than *L. radialis*, the two species might be able to coexist in the field. Assuming that both species overwinter in an early larval stage, *L. stabulans* would be expected to parasitize PSB larvae that mature early, during the first 3 weeks of June, whereas a later emergence of *L. radialis* would be better synchronized to parasitize hosts maturing later, during the end of June and early July.

Host suitability. *L. radialis* and *L. stabulans* failed to complete development on ECB larvae. Forty-nine of 62 ECB exposed to *L. radialis* pupated and, of the 13 hosts that died prematurely, only one contained a living third-instar larva which failed to pupate. One of the remaining dead hosts contained two encapsulated first-instar larvae. Of 120 ECB exposed to *L. stabulans*, 22 pupated, 19 died and 79 were still alive after 2 months. One of the dead larvae and 3 of the 79 live larvae encapsulated first-instar *L. stabulans*. These observations suggest that both *Lydella* species had difficulty parasitizing ECB due to their inability to penetrate the integument, to avoid encapsulation or to complete development before the death of the host.

Table V. Development of larvae and pupae of *Lydella radialis* and *L. stabulans* reared at 5 different temperatures and 16:8 L:D

Stage species	17°C	21°C	23°C	25°C	27°C
Larval <i>L. radialis</i>					
n	8	18	40	48	28
x (days)	26.0 ^a	17.2 ^a	12.2 ^a	10.1 ^a	8.5 ^a
S.E.	1.5	0.4	0.5	0.2	0.3
Range	22.0–32.0	15.0–21.5	8.5–23.0	8.5–13.0	6.5–11.0
Larval <i>L. stabulans</i>					
n	82	113	203	152	63
x (days)	16.9 ^a	11.6 ^a	9.8 ^a	8.4 ^a	9.2
S.E.	0.3	0.2	0.1	0.1	0.2
Range	12.0–24.5	8.0–17.5	7.0–13.5	6.5–16.5	7.5–14.5
Pupal <i>L. radialis</i>					
males					
n	20	5	11	21	12
x (days)	18.2*	12.6*	11.7 ^{a*}	11.3 ^{a*}	8.8
S.E.	0.2	0.5	0.3	0.1	0.3
Range	17.0–20.0	11.0–14.0	10.0–13.5	10.0–12.0	8.0–11.0
females					
n	16	7	19	19	12
x (days)	20.8 ^{a*}	14.6*	12.6*	12.6 ^{a*}	9.3
S.E.	0.3	0.4	0.2	0.2	0.2
Range	19.0–23.0	13.5–16.0	11.0–15.0	11.0–14.0	8.0–10.0
Pupal <i>L. stabulans</i>					
males					
n	38	46	79	48	22
x (days)	17.9*	12.8*	11.2 ^{a*}	10.4 ^{a*}	8.8*
S.E.	0.2	0.1	0.1	0.1	0.1
Range	16.0–20.5	11.5–14.5	10.5–12.0	9.0–12.0	8.0–9.5
females					
n	35	52	101	87	23
x (days)	19.4 ^{a*}	14.3*	12.3*	10.9 ^{a*}	9.5*
S.E.	0.2	0.1	0.1	0.1	0.1
Range	17.0–21.0	11.5–17.0	10.0–14.0	9.0–13.5	8.5–10.5

^a,*Denotes a significant difference ($P < 0.05$) between species^a, and between sexes* (Student's *t*-test, using Satterthwaite's approximation where variances were unequal).

Only one female *L. stabulans* successfully developed from 1 of 29 HVB treated with groups of 9 first-instar larvae and none of 52 HVB treated with groups of 4 first-instar larvae became parasitized. The surviving female lived 14 days as an adult, about 1 week less than average for her species (Table IV). No encapsulation was observed in dissections. Failure to parasitize was probably due to the inability of the larvae to penetrate the integument. Although it is unlikely that HVB would be preferred by *L. stabulans*, it is recorded as a host for *L. radialis* (Arnaud 1978).

Table VI. Developmental thresholds and thermal constants determined for the larval and pupal stages of *Lydella radicis* and *L. stabulans* using individual developmental rates*

Stage		t± S.E.	K±S.E.		
Species	n	(°C)	(degree-days)	r	Equation
Larva					
<i>L. radicis</i>	142	13.5±0.7	113.3±6.9	0.81	Y = -0.11879 + 0.00883X
<i>L. stabulans</i>	613	6.7±0.6	159.0±6.1	0.73	Y = -0.04232 + 0.00629X
Pupa					
<i>L. radicis</i>					
Males	69	6.5±0.8	193.4±10.0	0.92	Y = -0.03335 + 0.00517X
Females	73	7.9±0.8	193.8±10.6	0.91	Y = -0.04059 + 0.00516X
<i>L. stabulans</i>					
Males	233	6.6±0.3	184.8±3.5	0.96	Y = -0.03581 + 0.00541X
Females	298	7.4±0.4	190.1±4.7	0.92	Y = -0.03911 + 0.00526X

*Requirement for completion of life stage in 50% of the population.

According to Zwölfer (1962), *L. stabulans* may overwinter as a larva in several endophytic noctuids including *Papaipema* (= *Gortyna*) *leucostigma* (Harris), *Nonagria geminipunctata* Haw., *N. typhae* Haw., *Coenobia rufa* Haw., *Hypocaena* (= *Tapinostola*) *fulva* (Hampson) and *Hydraecia petasitis* Dbl. *P. leucostigma* is the only species recorded in North America but other species of *Nonagria* and *Hypocaena* have been recovered from wet areas in Canada and the U.S.A. (Forbes 1954) and could serve as alternative hosts for later generations of *L. stabulans*, if it becomes established⁴. They may also serve as alternate hosts for the indigenous species, *L. radicis*.

Macrocentrus blandus

Events in life cycle. Adults usually emerged in the early morning and mated immediately. Ovipositing females (Fig. 4a) frequently entered tunnelled-out corn stems in search of a host. Females parasitized more than one host; preferred instars ranged from first to fourth. Oviposition required 1 to 3 seconds. Parasitized larvae were noticeably larger in their final instar (Fig. 4b). However, because parasitization can dramatically affect host development (Vinson and Iwantsch 1980; Jones *et al.* 1981), this observation was not unexpected. In the present study, an extra moult may have accommodated the observed increase in size since head capsules of parasitized hosts were larger than those of non-parasitized larvae. A supernumary instar has been observed in the alfalfa looper, *Autographa californica* (Speyer), parasitized by *Apanteles yakutatensis* (Ashm.) (Madar and Miller 1983). Similar increase in body size of caterpillars due to the presence of braconid parasites has been observed by Slansky (1978). He found that larvae of the imported cabbageworm, *Pieris rapae* L., parasitized by *Apanteles glomeratus* L. had a 57% greater dry biomass as fifth instars than normal fifth-instar larvae.

About 5 to 6 weeks after parasitization, moving larvae of *M. blandus* were visible through the integument of the dying host (Fig. 4c), emerging within hours of the host's death (Fig. 4d). As observed by Zwölfer (1962), larvae began spinning after emergence and were enclosed in a common silk mat within 24 hours. Formation of pupal cocoons required an additional 24 hours. The pupal stage lasted about 3 weeks.

⁴Small numbers of *Lydella stabulans* and *Macrocentrus blandus*, reared for several generations in the laboratory, were released at the Guelph site in June and July, 1983.

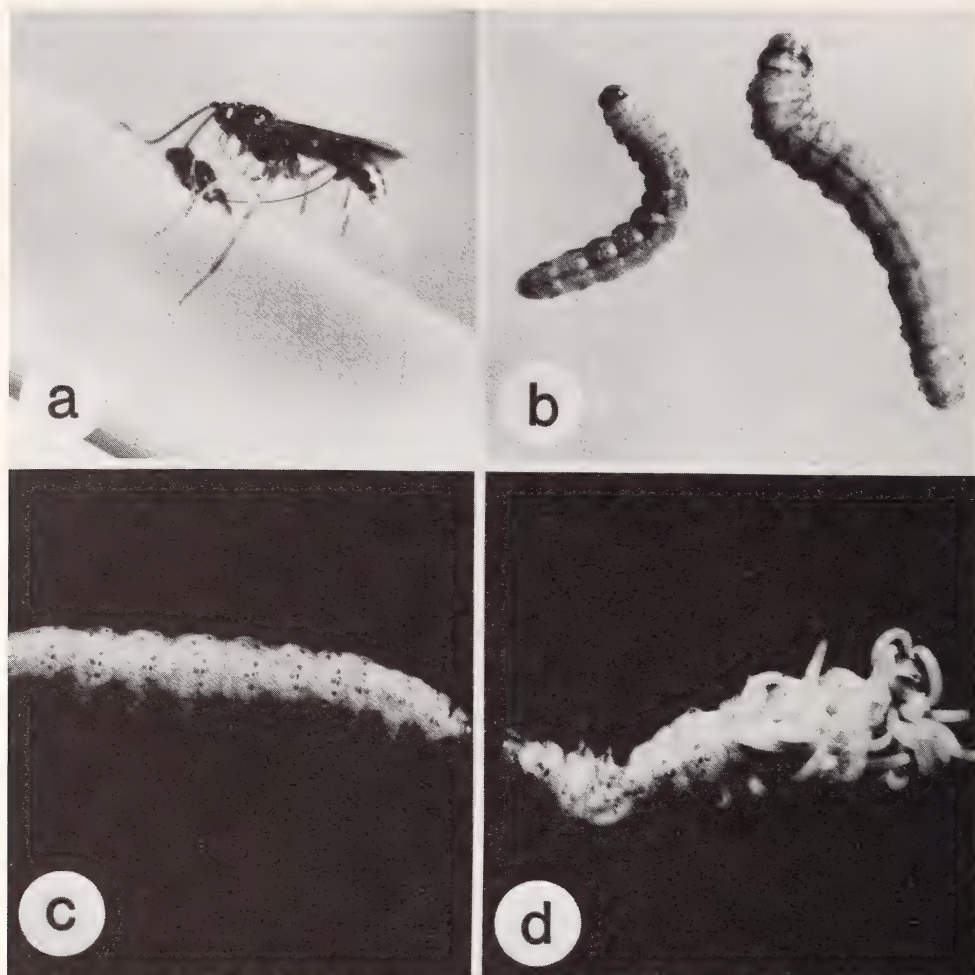


FIG. 4. Parasitization of *Hydraecia micacea* by *Macrocentrus blandus*: oviposition (a), unparasitized (left) and parasitized (right) hosts (b), parasitized host containing hundreds of developed larvae of *M. blandus* (c), larvae of *M. blandus* emerging from dead host (d).

Mating, longevity and fecundity. Mating, as observed by Zwölfer (1962), occurred immediately upon emergence of the female and lasted about 10 seconds (Table VII). Individuals of both sexes mated several times on the same day with males mating more frequently. Average longevity of females (4.8 days) was greater than that of males (3.9 days) (Table VII). The majority of mated females reared by Zwölfer (1962) died after 15 to 20 days with none living longer than 30 days, suggesting that rearing conditions used in the present study were inadequate. In the present study, a 10% honey solution was used whereas the 30% honey solution used in rearing different species of *Apanteles* (Madar and Miller 1983; McCutcheon *et al.* 1983) may have resulted in the higher survival reported. Madar and Miller (1983) found that the average longevity of *A. yakutatensis* was less than 3 days when given distilled water only, but increased to more than 16 days when a 30% honeywater solution was provided. Frequent misting of the cages in the present study may have diluted the already weak (10%) honey solution resulting in the premature death of adults.

Table VII. Mating duration, adult longevity and fecundity of *Macrocentrus blandus*

	Number examined	Mean $\pm$ S.E.	Range
Mating duration (sec.)	100 pairs	9.5 $\pm$ 0.4	3.5–23.0
Adult longevity			
males	13	3.9 $\pm$ 0.4	1–8
females	102	4.8 $\pm$ 0.2	1–9
Fecundity (total no. eggs)	4 virgin females	90.5 $\pm$ 1.8	87–96

Fecundity of virgin females 1 to 2 days old was about 90 eggs (Table VII) with approximately 45 eggs contained in each of 2 ovaries. *M. blandus* is thus probably a polyembryonic species since between 48 and 310 larvae were reared per host (17 parasitized hosts examined) and since on a few occasions only one sex (female) emerged from parasitized hosts. In rearings where both sexes emerged, females always outnumbered males at frequencies ranging between 74 and 93%. Females did not parasitize PSB until the day following mating, suggesting a 24-hour gestation period.

Rates of pupal development. Complete pupal development required 23 days at 17°C, falling to 13.5 days at 25°C. There was little difference in development between sexes (Table VIII). Thermal constants and developmental thresholds were 268°D_{4.9} for males and 245°D_{6.4} for females (Table IX), indicating that individuals of *M. blandus* developing on PSB in June complete pupation by mid summer, and thus presumably must find an alternative host to initiate the next generation.

Table VIII. Development of male and female pupae of *Macrocentrus blandus* reared at 5 different temperatures and 16:8 L:D

	17°C	19°C	Temperature 21°C	23°C	25°C
Males					
n	6	2	12	25	33
$\bar{x}$ (days)	23.0	20.3	16.5	14.8	13.5
S.E.	—	0.3	0.4	0.4	0.2
Range	—	20.0–20.5	16.0–21.0	13.0–22.0	12.0–16.0
Females					
n	84	115	131	208	140
$\bar{x}$ (days)	23.9	20.6	16.1	14.3	13.6
S.E.	0.2	0.0	0.3	0.1	0.1
Range	23.0–28.0	20.0–22.0	16.0–18.0	13.0–16.5	12.0–16.0

Table IX. Developmental thresholds and thermal constants determined for pupae of *Macrocentrus blandus* using individual developmental rates*

	n	t $\pm$ S.E. (°C)	K $\pm$ S.E. (degree-days)	r	Equation
Males	77	4.9 $\pm$ 1.1	268.1 $\pm$ 16.3	0.88	Y = -0.01815 + 0.00373X
Females	676	6.4 $\pm$ 0.5	244.5 $\pm$ 3.1	0.95	Y = -0.02613 + 0.00409X

*Requirements for completion of life stage in 50% of the population.

Acknowledgements

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SURVIVAL OF THE MOSQUITO PREDATOR *DUGESIA TIGRINA* (TRICLADIDA: TURBELLARIA), OVER THREE YEARS IN CATCH BASINS

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Field and laboratory populations of *Culex* spp. mosquito larvae were reduced over a single season by the planarian *Dugesia dorocephala* (Woodworth) in California (Legner *et al.* 1975) and by a smaller species, *Dugesia tigrina* (Girard), in Ontario (George 1978 and George *et al.* 1983). However, *D. tigrina* failed to control feral mosquitoes in temporary pools in North Dakota (Meyer and Learned 1981).

Catch basins of storm sewers have been identified as ideal breeding sites for *Culex pipiens* L. and *C. restuans* Theo., the species implicated in the transmission of St. Louis Encephalitis in Ontario (George 1983). The possible advantages of planarians over repeated applications of insecticides into catch basins have already been discussed (George 1978). However, it was not known if *D. tigrina* would survive a year or longer in catch basins. Hence, a 3-year test was conducted to determine if *D. tigrina* was capable of surviving for extended periods in catch basins and to determine factors contributing to the mortality of *D. tigrina*.

D. tigrina were collected from the under surfaces of stones in the Thames River on the University of Western Ontario campus in 1977. They were taken to the laboratory and reared in open, plastic, 20-liter pails. One-half-cm cut lengths of earthworms were used as food and replaced once a week. Twenty-five catch basins in the village of Komoka, 7 km southwest of London, Ontario, were selected in 1979 as having the cleanest appearing water that remained at least one-half meter in depth between rain storms. Styrofoam® floats, 25 cm square and 2.5 cm thick, were placed on the water in each basin 4 weeks before the planarians were introduced. Each October the floats were removed for the winter and replaced with new ones the following May. In 1980 the undersurfaces of the floats were inspected for planarians and the numbers recorded every two weeks, twice prior to, and 8 times following the introduction of 80 reared planarians to each basin on 15 July 1980. There were 10 inspections in 1981 and, as little new information was obtained after the first 4, there were only 4 inspections in May and June of both 1982 and 1983. During August of both 1981 and 1982, 25 new planarians were put into each of those catch basins from which planarians had not been detected the previous spring. In October of 1980, 25-ml water samples were collected from each of the 25 catch basins. The samples were taken to the laboratory and the pH of each determined the same day. On 12 March, 2 April, 7 May and 11 June 1983, the levels of dissolved oxygen were determined in all 25 basins with a YSI® Model 57 dissolved-oxygen meter equipped with a stirrer and the membrane maintained at a depth of 10 cm near the middle of the basins. Planarians, where present on 15 July 1981, were collected from floats and tested by exposure to mosquito larvae, as *D. tigrina* is the only planarian in the area known to prey on mosquito larvae. Data collection ceased on 31 July 1983.

Tree leaves which had accumulated in the sumps of catch basins were brought into the laboratory in March 1983 and volumes of 5.0, 10.0 or 22.5 liters of detritus were placed in each of three plastic containers. Each container was maintained at a total volume of 25 liters by adding water. Three containers without detritus served as controls. The levels of dissolved oxygen were determined twice weekly. Thirty laboratory-reared *D. tigrina*, longer than 1.5 cm, were placed in each container and monitored twice a week on the undersides of the same type of floats used in the catch basins.

Field tests. Prior to the introduction of *D. tigrina*, none was found on a float in any of the catch basins whereas, after their introduction on 15 July 1980, *D. tigrina* were present in all basins but one and on all inspections including the last on 31 October. In one basin none was found after 20 August. The following year (1981) no planarian was found in 9 basins. These 9 were re-inoculated in August 1981. Twelve basins had to be re-inoculated in August 1982. On 31 July 1983, when testing ended, planarians were absent from 13 basins. *D. tigrina* survived for 3 years in 8 of the 25 basins, for 2 years in 6 basins and for a year in 5 basins. *D. tigrina* failed to survive a year in the remaining 6 basins. All planarians, collected from floats in 12 basins on 15 July 1983, readily fed on mosquito larvae.

Acidity from rain was not a problem in October 1980 when pH averaged 7.3 with a range of 7.0 to 7.6 in the 25 basins.

For the 25 catch basins in 1983, average levels of dissolved oxygen, with standard deviations, and average temperatures, in brackets, were 3.8 ± 3.3 ppm (3.3°C) in March, 3.6 ± 3.0 (3.4°) in April, 2.6 ± 2.0 (9.2°) in May and 0.32 ± 0.43 (13.3°) in June. Highest levels of dissolved oxygen were 9.6 ppm in March, 9.0 in April, 7.5 in May and 1.8 in June. Thus the lowest levels of dissolved oxygen occurred in conjunction with the spring rise in temperature in June when there were 0.1 ppm or less in 13 basins and 0.2 or more in 12. Although *D. tigrina* is remarkably tolerant to low levels of dissolved oxygen, most of these values, recorded at 10 cm, are below the lethal level of around 0.3 mg per liter (ca 0.3 ppm) (Russier-Delome 1974). Levels of dissolved oxygen were often slightly higher, but variable, at depths of less than 10 cm. In those basins with 0.1 ppm or less, at 10 cm, planarians were still alive on floats at the surface in 4 basins but absent from 9. Of those basins with 0.2 ppm or more, planarians were alive in 8 but absent from 4. Although the low levels of dissolved oxygen recorded here may well account for much of the planarian mortality, other mortality factors were involved in some basins. In 2 basins, mortality occurred shortly after small amounts of turpentine and paint were discarded into the basins by homeowners.

Laboratory tests. Different amounts of maple and oak leaves, collected from catch basins in February 1983, lowered dissolved-oxygen levels within 2 days from 8.1 ppm in the control to 2.2, 1.1 and 0.1 with 20, 40, and 90% wet leaves respectively. None of 30 *D. tigrina* survived 1 day with 90% of the volume occupied with leaves. When 50-ml samples of water were removed from the latter container, *D. tigrina* survived with aeration but died within 3 hours in non-aerated samples. The planarian count per float over the 7-week test period (average $\pm$ SD) was 17.5 ± 4.8 with the controls, 24.9 ± 4.4 with 20% leaves and 24.0 ± 11.8 with 40% leaves.

Hence, low levels of dissolved oxygen during June, caused by the leaves which fell into catch basins the previous fall, were low enough to account for some, but probably not all, of the mortality of *D. tigrina* in catch basins. In 8 of 25 catch basins *D. tigrina* lived 3 consecutive years without further introductions. As conditions vary between catch basins, areas and years, there probably is no sure way of predicting if *D. tigrina* will survive in any given catch basin containing permanent water which appears to be clear.

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**HABITAT EFFECTS ON LARVAL MORTALITY
IN THE FOREST TENT CATERPILLAR,
MALACOSOMA DISSTRIA (LEPIDOPTERA: LASIOCAMPIDAE)**

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Although various studies have been carried out on outbreak populations of *Malacosoma disstria* Hübner (e.g., Hodson 1941, Sippell 1957, Ives 1973, Witter 1979), there is a paucity of work on between-outbreak populations because of the difficulty of locating the caterpillars (Hodson 1941). Here, we present preliminary evidence which suggests that this difficulty may arise, in part, because between-outbreak populations are confined to wet lowland forest by differences in caterpillar mortality between wet and dry forest habitat. We were led to this hypothesis by the fact that we have been unable to collect the caterpillar from dry upland areas between outbreaks, but could collect them from wet lowland areas at the same stage of the cycle. This "differential-mortality" hypothesis was used as an essential component of a general model for the insect outbreak phenomenon (Harmsen *et al.* 1976; Rose and Harmsen 1978, 1981). The model used the hypothesis of differential mortality associated with limited female dispersal rather than the alternative hypothesis of oviposition site preference and free female dispersal. We considered it important to carry out experimental tests of the possible validity of this hypothesis.

On 13 May 1978, newly eclosed larvae obtained from eggs collected from an outbreak area near Sudbury, Ontario, were released on trembling aspen near Lake Opinicon, Ontario. Three different types of sample trees received 200 larvae each: (A) six trees located in wet, swampy, lowland areas with stagnant water among trees in spring and early summer, (B) six trees on dry upland with adhesive placed around their trunks to exclude non-flying predators, and (C) six trees on dry upland without adhesive. The experimental trees were of similar size varying from 1.8 to 3 m high, but their spatial isolation and degree of shading differed, so that there were some differences among the trees used in each habitat. Because the trees were chosen according to their similarity to the first tree, and good likenesses became less available as further trees were chosen, a "tree-sequence" effect may have been introduced and is discussed later.

The larvae were retrieved from the sample trees on 20 May, during the time of the moult to second instar, and counted. Thirty larvae from each tree were selected at random and reared in paper cups. Each cup contained fifteen larvae and was provided daily with fresh foliage of trembling aspen. All cases of mortality and their causes were recorded. All species of parasitoids were identified.

Observed predation was less than 3%, but unexplained mortality during the first instar, and mortality of later instars caused by parasitism which had been initiated during the first instar, were both higher. The statistically significant (two-way analysis of variance for habitat and tree-sequence effects) differences in percent retrieval indicate higher survival in the lowland habitat than in either upland habitat. An adhesive barrier on the lower stem of upland trees did not increase survival of caterpillars significantly. The lower percent mortality due to parasitism in lowland habitat is significant only at the 10% level. A significant tree-sequence effect indicates the importance in field experiments of either using close to

identical host plants, or including host-plant variance in such a way that its effect can be separated statistically from other effects.

The observed effects may be the result of habitat selection on the part of predators and parasitoids. Ground predators may be "passively selecting" caterpillars in dry forest because of their inability to get to lowland trees. This is suggested by the intermediate number of larvae retrieved from protected upland trees. Both parasitoid species (*Rogas malacosomatos* Mason and *Phobocampe clisiocampae* (Weed)), enter the first instar of *M. disstria* and kill the third instar; they then pupate on the ground beneath the trees. This suggests higher parasitoid mortality on trees located in marshy lowland areas than in drier places. Perhaps these parasitoids have evolved a mechanism of active habitat selection which leads them to avoid lowland areas. Microclimatic and nutritional differences between wet and dry habitats may also have important effects on larval mortality.

Though our results are preliminary in that they are confined to a small fraction of the complete forest tent caterpillar life cycle, they do conform to expectations, and lend tentative validity to the basic "differential-mortality" hypothesis. Further research is being planned to cover habitat effects on later larval instars.

Table I. Mortality and percentage parasitism of first-instar larvae of *Malacosoma disstria* in three habitats. Each treatment consisted of 6 batches of 200 larvae each

Habitat	Observed Predation (mean)	Retrieved 1st-instar larvae (mean)	Total 1st-instar mortality ^a (%)	Parasitism during 1st instar ^b (%)
A: lowland trees	0.16	172.5	13.8	5.3
B: "protected" upland trees	1.7	149.3	25.4	12.7
C: "unprotected" upland trees	2.2	145.2	27.4	12.8

^aMortality significantly different between habitats (F statistic, $P < 0.05$).

^b Percentage parasitism marginally different between habitats (F statistic, $P < 0.10$).

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COMPARATIVE SUSCEPTIBILITY OF CHRYSANTHEMUM CULTIVARS TO *LIRIOMYZA TRIFOLII* (DIPTERA: AGROMYZIDAE)

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Liriomyza trifolii (Burgess) is a major pest of chrysanthemum in Ontario (Broadbent 1982). Resistance to insecticides in this leafminer has dictated the urgent need for an integrated pest management (IPM) strategy for its control. One tactic useful in IPM programs is the selection of cultivars resistant to pest species. Webb and Smith (1969) found differences in duration of larval development of *L. munda* in different chrysanthemum cultivars in a laboratory study. Schuster and Harbaugh (1979) evaluated leafminer, *L. sativae*, damage to 21 spray-type and 9 standard-type cultivars grown outside in ground beds under polypropylene shade cloth in Florida. Relying on a natural influx of leafminer into the crop, they found wide differences in damage among the spray cultivars. Oetting (1982) in Georgia and Alverson and Gorsuch (1982) in South Carolina found a range of susceptibility in pot chrysanthemum varieties to *L. trifolii* which had become the dominant leafminer in commercial greenhouses in these states. The objective of our study was to evaluate leafminer damage on 17 cut chrysanthemum cultivars commonly grown in the Niagara peninsula, Ontario, by introducing leafminers into a commercial-type greenhouse.

The experiment was conducted in a 16.8×6.9 m glasshouse (Horticultural Research Institute of Ontario, Vineland Station, Ont.) using chrysanthemum cultivars (15 spray-type and 2 standard-type) commonly grown in the Niagara region. Rooted cuttings were planted in pasteurized ground beds (15.2×15.2 cm centre spacing) on 20 May 1982. Each cultivar was planted in 3 blocks (3 replicates) of a 15×1.2 m bed; 16 plants per replicate. The greenhouse was maintained at a minimum air temperature of 20/18°C for day/night. Temperatures ranged between 20 and 26°C during May and June with higher temperatures during July (20-32°C). The plants were watered through 2 perforated plastic lines per bed. Fertilization took place simultaneously with the irrigation using standard recommendations. Natural long days for vegetative growth were provided until 7 June at which date the short-day treatment (11h L:13h D) was started to initiate flowering.

Leafminer pupae were introduced into the greenhouse on 10 June 1982 (50 pupae/dish; 10 petri dishes) and 18 June (25 pupae/dish; 10 dishes) with one dish placed every 1.5 m of row. Adult leafminers were monitored weekly by counting those collected on 3, 17×10 cm yellow sticky traps which were placed over the bed on 12 July. No chemical controls for leafminer were used, however pirimicarb (Pirimor, 0.55 g/L) was applied 3 times (16, 22 and 29 June) to control aphids and fenbutatin oxide (Vendex, 1 g/L) was applied 7 times (7, 14, 20, 27 July and 4, 10, 17 August) to control spider mites, *Tetranychus* spp.

Leafminer damage was evaluated at harvest (6 August 1982), 11 weeks after planting. Three plants per cultivar per block were removed, avoiding any plants on the ends of rows or row edges where mines per leaf are generally most numerous (Price *et al.* 1982). The mines on the top 10 open leaves/stem were counted. The top leaves were assessed since these are on the marketable part of the plant. Numbers were transformed by $\sqrt{x} + 0.5$ for statistical analysis (3-way analysis of variance with means separated by Duncan's multiple range test, 5% level).

The percent emergence ($\pm$ S.D.) of leafminer adults from pupae which were used to infest the greenhouse was $83.6 \pm 3.7\%$ and $72.4 \pm 14.0\%$ for releases 1 and 2 respectively (determined 2 weeks after releases). Therefore the initial population in the greenhouse was approximately 600 leafminers, or 300 females assuming a 1:1 sex ratio. At harvest 8 weeks later (6 August), or after approximately 3 generations, the leafminer population had increased to greater than 600 adults/stickyboard trap/week.

Although leafminer pupae were introduced on 10 June, the first mine was not observed until 23 June. The first empty mine was found on 28 June, indicating a generation turnover of about 18 days. The adult population, as monitored by stickyboard traps, reached a peak of 700 flies/board/week on 10 August.

Table I. *Liriomyza trifolii* leafmines in foliage of selected chrysanthemum cultivars

Cultivar	Mean no. mines on top 10 leaves/stem ¹
White Iceberg	37.1a
Yellow Iceberg	35.0a
Polaris	24.6 b
Gem	24.3 b
Florida Marble	22.3 b
Copperary	22.0 b
White Marble	21.9 b
Dark Chip	20.4 b
Plume	19.9 bc
Amber	19.6 bc
Blue Marble	18.6 bc
Yellow Marble	17.0 c
Flame Belair	14.4 c
Pinocchio	6.6 d
Southern Gold	3.9 e
Colonel Comfort	2.8 ef
Statesman	1.3 f

¹ Means before $\sqrt{x} + 0.5$ transformation; means followed by the same letter are not significantly different ($P < 0.05$) as determined by Duncan's multiple range test.

There were significant differences in leafminer damage for the 17 cultivars of chrysanthemum (Table 1). The mean number of mines per 10 top leaves ranged from 37.1 for 'White Iceberg' to 1.3 for 'Statesman'. White and yellow Iceberg spray-type flowers were the most susceptible, whereas the standard-type, 'Colonel Comfort', and the button pom-pom, 'Statesman', were the most resistant to leafminers. The two standard cultivars, 'Colonel Comfort' and 'Southern Gold' had significantly fewer ($P < 0.05$) mines than 14 other cultivars. This agrees with the findings of Schuster and Harbaugh (1979) who concluded that standard-type cultivars had generally fewer mines than spray-type ones. Although the

Liriomyza species which Schuster and Harbaugh studied was identified as *L. sativae*, they now believe the species was in fact *L. trifolii* (Schuster pers. comm. 1983). They suggested that growers reduce production of the most susceptible cultivars. In fact, in Ontario greenhouses growers have reduced the production of Iceberg varieties. 'Polaris', a cultivar which some growers have used in place of Iceberg, was statistically less susceptible than 'Iceberg' but sustained heavy damage in our study. Schuster and Harbaugh (1979) found no significant difference in mines per stem between 'Iceberg' and 'Polaris'.

Counts of the mines per top 10 leaves were readily made at the level of leafminer infestation in this study. However, in Oetting's 1982 study, where greater numbers of leafminers were present, counts of mines/leaf were not adequate since all cultivars became heavily mined and mines became intermingled. At these high damage levels, Oetting found that the number of pupae dropping into trays was a more effective way to detect differences among cultivars.

Further work is required to elucidate the mechanisms of cultivar resistance in chrysanthemums and to determine whether these mechanisms can be exploited in future breeding and used in IPM programs.

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INSECTS ASSOCIATED WITH FLOWERING TEASEL, *DIPSACUS SYLVESTRIS*, AT DUNNVILLE, ONTARIO

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From 5 to 20 August 1978, insects were collected from flowers of teasel. *Dipsacus sylvestris* Huds., growing at roadsides at the south border of Lot 1, Concession IV, South of Dover Road, Dunn Township, Haldimand County, a locality now annexed to the Town of Dunnville.

Insects were collected during the period from noon to 2 pm and were pinned and labelled. Most of the insects were identified by staff members of the Biosystematics Research Institute, Agriculture Canada, Ottawa: D. Brown (Heteroptera), J.M. Campbell (Phalacridae), B.E. Cooper (Calliphoridae), H. Goulet (Tenthredinidae), M. Ivanochko (other Hymenoptera), J. McNamara (Cantharidae), L. Le Sage (Chrysomelidae), J.R. Vockeroth (Syrphidae), H.C.W. Walther (Muscidae). Butterflies and the moth were identified by the author. All specimens are deposited in the collection of the Department of Zoology, University of Western Ontario, except those noted as "kept" which are in the National Collection, Ottawa. Among the butterflies, only specimens of Hesperiiidae were collected and put in the university collection.

Of the 188 insects collected, 10% were Heteroptera, 14% Coleoptera, 18% Lepidoptera, 25% Diptera and 56% Hymenoptera (Table I). The ambush bug, *Phymata wolfii*, was a predator on insects visiting the flowers. The three species of beetles were actively crawling over the flowers. *Olibrus* beetles were capable, because of their small size, of crawling down into the flower-tubes. Flies were scarce on the flowers, as compared with their abundance on other kinds of plants at Dunnville (Judd 1975, 1978b, 1980). This was evidently owing to their inability to insert their short mouth-parts into the flower-tubes. The moth and butterflies were active feeders, easily inserting their uncoiled mouth-parts into the flowers. More than half of the number of insects were bees. Among these, the most active pollinators were bumble-bees, *Bombus* spp., with their pollen baskets filled and their bodies well dusted with the light yellow pollen of the flowers.

Table I. Insects collected from flowering teasel, *Dipsacus sylvestris*

Order Family	No.	Species Collected	Dates (August)	Notes and Previous Records
HETEROPTERA				
Miridae	6	<i>Plagiognathus politus</i> Uhler	6-17	on cinquefoil (Judd 1978b), basswood (Judd 1980)
	6	<i>Lygus lineolaris</i> (P. de B.)	7-19	on dandelion (Judd 1971), bloodroot (Judd 1977), hawkweed (Judd 1978b)
	2	<i>Adelphocoris lineolatus</i> (Goeze)	6, 8	on Compositae (Blatchley 1926)
Phymatidae	5	<i>Phymata wolfii</i> Stal	6-19	on 8 Aug. one bug was grasping a bee, <i>Augochlorella striata</i>

Order Family	No.	Species Collected	Dates (August)	Notes and Previous Records
COLEOPTERA				
Cantharidae	13	<i>Chauliognathus pennsylvanicus</i> DeG.	13-20	in flower heads of Compositae (Blatchley 1910)
Phalacridae	9	<i>Olibrus</i> sp.	13-19	on musk-mallow (Judd 1974)
Chrysomelidae	5	<i>Diabrotica undecimpunctata howardi</i> Barber	6-16	on hawkweed (Judd 1978b)
LEPIDOPTERA				
Sphingidae	1	<i>Hemaris thysbe</i> (Fabr.)	6	feeding in daytime at flowers (Hodges 1971)
Danaidae	11	<i>Danaus plexippus</i> L.	5-20	this and the following nine butterflies occur commonly at Dunnville (Judd 1963)
Satyridae	4	<i>Cercyonis pegala</i> (Fabr.)	12-18	
Nymphalidae	4	<i>Vanessa virginiensis</i> (Drury)	12-18	
	2	<i>Vanessa atalanta</i> (L.)	12, 13	
	1	<i>Boloria toddi</i> (Holland)	20	
Pieridae	4	<i>Colias eurytheme</i> Boisduval	12-16	
Papilionidae	1	<i>Pieris rapae</i> (L.)	12	
	3	<i>Papilio polyxenes asterius</i> Stoll	5-15	
Hesperiidae	1	<i>Polites coras</i> (Cramer)	20	
	1	<i>Polites themistocles</i> (Latr.)	18	
DIPTERA				
Syrphidae	1	<i>Metasyrphus</i> sp.	5	
Calliphoridae	1	<i>Pollenia rudis</i> (Fabr.)	13	on bloodroot (Judd 1977), dogwood (Judd 1975)
Muscidae	1	<i>Musca domestica</i> L.	8	in aphid colony on thistle (Judd 1978a)
HYMENOPTERA				
Tenthredinidae	1	<i>Caliroa cerasi</i> (L.)	13	pear sawfly, on Rosaceae (Muesebeck <i>et al.</i> 1951)

Order Family	No.	Species Collected	Dates (August)	Notes and Previous Records
Halictidae	3	<i>Dialictus versans</i> (Lov.) - 2 kept	6-13	this and other bees in Halictidae on flowers (Judd 1975, 1978b, 1980)
	4	<i>Dialictus viridatus</i> (Lov.) - 2 kept	6-9	
	1	<i>Dialictus nymphaerum</i> (Robt.)	6	
	10	<i>Lasioglossum zonulum</i> (Sm.) - 3 kept	6-15	
	1	<i>Lasioglossum</i> <i>leucozonium</i> (Schr.) - 1 kept	8	
	23	<i>Augochlorella</i> <i>striata</i> Prov. - 5 kept	6-13	
Megachilidae	1	<i>Megachile</i> <i>centuncularis</i> (L.)	20	bees in Megachilidae and Apidae on dogwood (Judd 1975), hawkweed and cinquefoil (Judd 1978b), basswood (Judd 1980)
	1	<i>Megachile latimanus</i> Say	14	
Apidae	28	<i>Bombus bimaculatus</i>	5-20	
	14	<i>Bombus vagans</i> Sm.	5-20	
	3	<i>Bombus impatiens</i> Cress.	7, 6, 18	
	4	<i>Bombus griseocollis</i> DeG.	5-9	
	1	<i>Bombus borealis</i> Kby.	19	
	1	<i>Bombus sandersoni</i> Frank	5	
	2	<i>Bombus perplexus</i> Cress.	5, 8	
	2	<i>Psithyrus citrinus</i> (Sm.)	5, 18	
	1	<i>Anthophora terminalis</i> Cress.	5	
	3	<i>Melissodes desponsa</i> Sm.	5	
	2	<i>Apis mellifera</i> L.	6, 9	

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ONION MAGGOT DEVELOPMENT IN A BACTERIA-RICH ENVIRONMENT WITHOUT ONION TISSUE

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The absence of bacteria slows the development of *Delia antiqua* (Meigen) larvae on some onion cultivars (Schneider *et al.* 1983), and makes development impossible on the leaf tissue of others (Marshall and Eymann 1981). Although larvae will develop on axenic artificial diets, the presence of bacteria accelerates this development (Friend *et al.* 1959). The improvement in food quality resulting from the addition of bacteria to the food of several other species of Muscomorpha larvae, including house fly larvae (Levinson 1960) and olive maggots (Hagen 1966), has been clearly demonstrated. In the foregoing studies, bacteria supplemented food sources which contained many of the essential nutrients such as amino acids and vitamins. This note reports *D. antiqua* larval development on a substrate rich in bacteria but lacking onion.

Caged adult *D. antiqua* were given distilled water, dead powdered yeast and sugar during routine colony maintenance. The water was provided on a Kendall® (Toronto, Canada) absorbent cotton wick in a 125-ml Erlenmyer flask. In the absence of an oviposition dish, the flies oviposited on the wet cotton wick. The flies defecated on the cotton, and a rich growth of bacteria developed on the wick. In this wick, 6 maggots developed, pupated, and 2 became adults (one of each sex). When maintained as above, they mated and the female subsequently laid 35 viable eggs of which 25 became adults when reared on bisected onion.

Processed (bleached) cotton contains 99% cellulose (Ward 1955), and distilled water contains only trace quantities of inorganic nutrients. The nutrient content of the fecal matter is not known; however, it is unlikely that the faeces would contain appreciable quantities of the 10 amino acids (Friend *et al.* 1957) and 8 vitamins (Friend and Patton 1956) essential to onion maggot development. The maggots appear to have obtained most of these complex nutrients from the bacteria growing in the wet cotton. Bacteria from the wick were plated on nutrient agar and identified as *Escherichia coli*, using morphological and biochemical tests with EMB and IMVic medium (K. Chau, personal communication). *E. coli* can grow on a simple mixture of salts and a carbon chain such as sodium citrate (Sober 1970). No other species of microorganism was detected on the wick.

Although onion maggots can develop on a substrate other than decaying onion, this is probably a rare event in nature. The female flies are strongly attracted to volatiles given off by healthy or decaying onion bulbs (Dindonis and Miller 1980) and oviposit on or near the plants. It is this ovipositional behavior that establishes the link between the insect and the host plant. Although the host range of *D. antiqua* appears limited to specific members of the genus *Allium*, namely onions, leeks and garlic (Jones and Mann 1963), the present study shows that these tissues do not supply any exotic essential nutrients. Under natural conditions, the microorganisms associated with the decay induced by maggots in onion tissue probably constitute an important source of nutrients.

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**CHEMICAL CONTROL OF CARROT WEEVIL,
LISTRONOTUS OREGONENSIS (COLEOPTERA: CURCULIONIDAE), AND
DAMAGE TO CARROTS IN THE HOLLAND MARSH, ONTARIO.**

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The carrot weevil (CW), *Listronotus oregonensis* (LeConte), has become a serious pest of carrots, and, to a lesser extent, celery in the Holland Marsh. Recommendations for its control appeared in the Ontario Ministry of Agriculture and Food Publication 363, "Vegetable Production Recommendations", from 1965 to 1969, but there is no published information on its pest status in Ontario in those years. In 1970, when work on development of an integrated pest management program for carrots in the Holland Marsh was begun, CW was found on only a few farms near the north end of the main marsh and was also present about 15 km northeast in the Keswick Marsh. Since then, it has spread to farms on both sides of Highway 400 in the Holland Marsh and has been reported from the contiguous Bradford and Colbar marshes and in addition at the more northerly Cookstown marsh (D.J. Madder and F.L. McEwen, unpublished report).

Although the increase has coincided with the banning of DDT in Ontario, Martel *et al.* (1975) found that DDT was not particularly toxic to CW. They identified a number of insecticides that were toxic to the insect in the laboratory. When carbofuran, as a granular treatment applied in the furrows at seeding, was first tested for use in controlling the carrot rust fly, *Psila rosae* (Fab.), it was also effective against CW (Stevenson 1976). However, in later trials (unpublished) and in commercial usage, none of the insecticidal programmes recommended for carrot rust fly control have provided satisfactory CW control. As CW increased in importance, the need for an effective insecticide became more urgent. This paper reports results of field trials with several insecticides for CW control on carrots in the Holland Marsh.

Trials were conducted on muck soil in the Holland Marsh on plots grown exclusively for this study. Each plot consisted of 3 rows of carrots 12 m long, seeded with a Planet Jr. seeder. Treatments were replicated 3 times in a randomized block design. Rows were 40 cm apart; plots were separated by a blank row and by headlands 3 m wide between blocks. Sprays were applied with a pushcart power sprayer designed by Menzies and Fisher (1975) that delivered 1100 l/ha at ca. 2100 kPa. Treatments were evaluated by collecting 200 carrots from the centre row of each plot and determining the percentage injured by CW.

CW overwinters in the adult stage in and near fields infested the previous year. The adults become active in early to mid May, but do not begin ovipositing in the new crop of carrots until after the first-true-leaf stage (Stevenson 1977). Therefore, the first spray was applied each year after the development of the first true leaf.

In 1974, six insecticides (Table 1) were tested on carrots, cv. Gold Pak, seeded 21 May and sprayed 5 times (7, 12, 19, 24 June and 2 July). Five applications were made because the insecticides were also being tested against the carrot rust fly, but only the first 3 applications were likely to influence CW activity. Samples for evaluation were collected 15 and 27 August.

In 1975, 3 applications each of phosmet and phosalone (20, 26 June, 3 July) were made to carrots, cv. Spartan Fancy, seeded 29 May. Samples were collected 6 August for evaluation.

In 1977, carrots, cv. XP 159, were seeded 10 May, at which time carbofuran was applied in the seed furrow to two of the 6 treatments. Sprays were applied 31 May (except for azinphosmethyl-carbofuran treatment), 9 and 20 June. Samples for evaluation were collected 4 August.

In 1978, plots were established at two sites in the Holland Marsh. Carrots, cv. Long Imperator, were seeded 11 May (site 1) and 19 May (site 2). Sprays of phosmet and phosalone were applied 6 and 20 June (site 1) and 14 and 28 June (site 2). Samples for evaluation were collected 9 (site 1) and 16 (site 2) August.

In the 1974 trial, carbofuran, chlorpyrifos, phosmet, and tetrachlorvinphos were highly effective against CW (Table 1). Methyl parathion and ethyl parathion, used at lower rates, were less effective, although they reduced the CW injury significantly.

Table I. Efficacy of various insecticides for control of the carrot weevil on carrots in organic soil, Holland Marsh, 1974-78

Year (variety)	Insecticide and formulation	Rate (kg a.i./ha)	Mean % injured by CW ^a	
1974 (Gold Pak)	Tetrachlorvinphos (Gardona 75W)	1.1	0.3a	
	Phosmet (Imidan 50W)	1.1	1.3a	
	Chlorpyrifos (Lorsban 4E)	1.1	0.2a	
	Carbofuran (Furadan 4.8F)	1.1	1.3a	
	Parathion 15W	0.3	2.5ab	
	Ethyl parathion (Pencap 22E)	0.6	10.7 b	
	Control		27.1 c	
1975 (Spartan Fancy)	Phosmet (Imidan 50W)	1.1	0.0a	
	Phosalone (Zolone 30W)	1.1	0.7a	
	Control		29.7 b	
1977 (XP159)	Carbofuran (Furadan 10G)	2.2	0.8a	
	Carbofuran (Furadan 10G)	2.2	0.0a	
	+ Azinphosmethyl (Guthion 50W)	+ 1.1		
	Tetrachlorvinphos (Gardona 75W)	1.1	0.2a	
	Phosmet (Imidan 50W)	1.1	0.3a	
	Azinphosmethyl (Guthion 50W)	1.1	0.0a	
	Control		6.5 b	
1978 (Long Imperator)			Site 1	Site 2
	Phosmet (Imidan 50W)	1.1	0.3a	0.7a
	Phosalone (Zolone 30W)	1.1	1.3a	7.7a
	Control		3.0a	29.0 b

^aWithin one trial, means followed by the same letter are not significantly different ($P < 0.05$), Duncan's Multiple Range Test.

The 1975 trial confirmed the efficacy of phosmet and showed that phosalone was also effective against CW.

The 1977 trial confirmed the efficacy of phosmet and tetrachlorvinphos and showed that azinphosmethyl, either alone or in combination with a carbofuran furrow treatment, was very effective. Although the granular carbofuran treatment to seed furrows, without foliar sprays, was also effective in this trial, this treatment has not been generally effective against CW either in commercial usage in the marsh or in recent experimental trials (unpublished). Felsot *et al.* (1982), and Read (1983), reported rapid microbial breakdown of carbofuran in soils with a history of continuous carbofuran usage. The ineffectiveness of carbofuran in commercial use in the Holland Marsh might also be due to microbial breakdown associated with its repeated use. The site on which the 1977 trial was conducted had little or no previous treatment with carbofuran.

The 1978 trial showed that two sprays of phosmet or phosalone were effective against CW.

Since the completion of these experiments, phosmet has been registered for CW control in Canada. If a need arises for registration of additional insecticides for CW control, the efficacy of phosalone, chlorpyrifos and azinphosmethyl renders them worth considering.

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